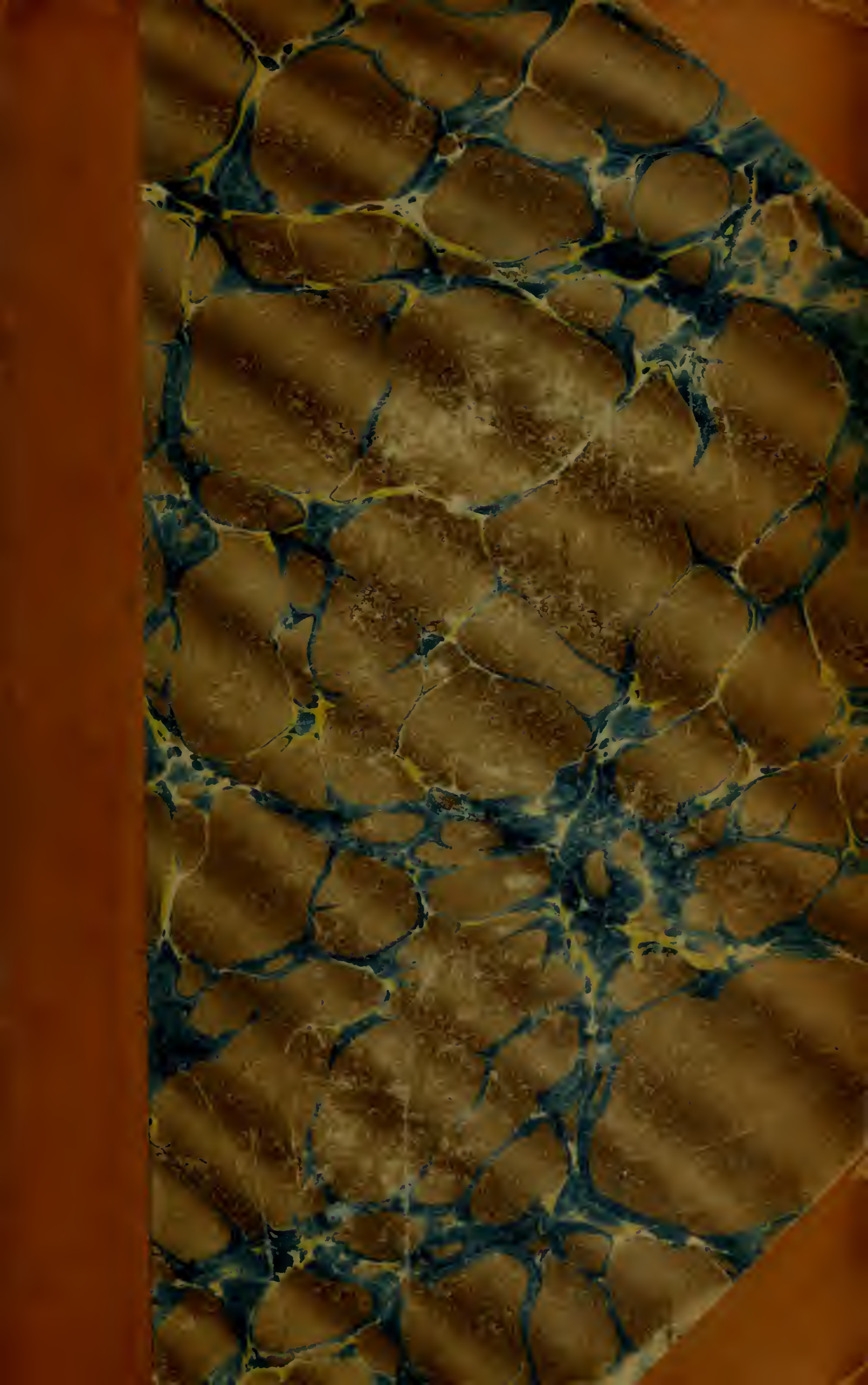

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OF THE

FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

Dr. H. W. Jayne, Chairman; Mr. Edwin Swift Balch, Ph.D., Dr. Persifor Frazer, Mr. Louis E. Levy, Prof. Coleman Sellers, E.D., Committee on Publications;

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THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, February 18, 1903.

The Bacterial Disposal of Sewage.

By G. EVERETT HILL.

It will be my endeavor to night to condense within the limits of your patience the salient points which will explain (1) why sewage disposal is of vital interest to a community, (2) the various methods of sewage disposal in use, and (3) the comparative value of these methods.

Whether recognized or not, the mainspring of all human activities, whether physical, mental or spiritual, is the desire to acquire. To get—to have—to enjoy—these are the longings of all; differing widely in manifestation with the individual, but springing from the same principle.

Our lives have grown very complex. Things which our ancestors never saw are necessities to-day; and what we see in Nature's storehouse and want, we do not hesitate to appropriate. We kill the cattle, we cut down the forests, we tear the iron and coal from the bowels of the unwilling earth; we even appropriate the air and sunshine and use them as slaves to drive our motors and paint our pictures. All this is progress, and a certain measure of progress in acquisition is called civilization.

But acquisition and use must always be followed by consumption and rejection of the products of consumption. Our track of progress is really a trail of desolation strewn with ashes, excrement and rubbish. Even the air is polluted and the sunshine darkened by the smoke and noisome exhalations poured from our factory chimneys. In our instincts of rejection we are still little more than savage. Until *very* recently, few, save perhaps the barbarous Chinaman, dreamed of putting his wastes to any use. Things which we do not want we throw away, and that is the end of our interest in them. Even the poet—who is supposed to be an idealist—instead of putting his rejectamenta into the rubbish barrel or some other suitable place, unblushingly says:

> " Behind us, *in our path*, we
> Cast the broken potsherds."

The sailor alone, who has had an experience denied to the poet, has modified this promiscuous discarding of wastes by insisting that hot ashes—and certain other things—be not thrown to windward.

Seriously, I have not overstated the case. Can we rightly boast of national civilization when less than 4 per cent. of the communities in our country have adopted means for the hygienic disposal of filth; and when the sixth city of the land is riddled—under buildings as well as under yards and streets—with cesspools, whose overflow babbles noisily and noisomely in the street gutters?

But man is learning. So long as the area surrounding his habitation was large, he suffered little recognized inconvenience. But when the farm became a village and the village a town—as the land was divided and subdivided and the houses and population multiplied—he was brought into closer relations with his own offscourings; offense and disease resulted, and it gradually dawned upon his consciousness that either he or it must get off the premises. Consequently, he sought for a new place in which to throw it, and, grumbling about the cost, built a sewer to the nearest stream. He thought only of transferring the offense to some point beyond the reach of his senses—not of destroying it.

But an epidemic broke out in a town below, which used this stream as a source of water supply; and the resulting suffering and death were found to be entirely chargeable to the community which had "thrown away" its sewage into the stream. The courts were invoked, and future pollution of the stream was forbidden. What could be done with the sewage, now greater in volume than ever and still increasing? The ocean was too remote to be reached; there was no mighty river available which could serve as an outlet.

Then man began to think and to study. He found that sewage was not irredeemable filth. He learned that nature, if encouraged, would turn his foul and poisonous offscourings into clean and harmless mineral forms, and would restore to contaminated water its original purity. He learned, moreover, that this could be done without offense, and close to his own home; that there need be no accumulation of filth, nor any pollution of streams or other infringement of a neighbor's rights; that death-rates can be lowered; that suffering and the expense of sickness can be lessened, and the period of productiveness lengthened.

He *thought* for a while that he had learned more than this. Necessity is a very fecund mother of invention; but, sad to say, prescience is not always the father. The offspring were patents—patents by the score, by the hundred —myriads of patents for "improved" processes of sewage disposal. The sifting of this innumerable company of patents was a long and tedious process. Most of them proved worthless. A few are of great value. The most beautiful children are not always the best, and the processes which brought the bitterest disappointment were those beatific ones which promised financial return from the recovery of valuable constituents of the refuse. Fortunes untold have been sunk in the attempt to make the collection and treatment of sewage profitable. It is true that some pecuniary return may be expected from processes which are available for use under certain conditions, and such return should be welcomed as a valuable factor in reducing the cost of treatment; but it is not safe to build upon any foundation other than this; *i. e.*, that the disposal of refuse is a vital and costly necessity, a just tax upon those whom it benefits, and that its charges must be estimated as a part of the price of living and paid accordingly.

Self-betterment *per se* cannot be forced upon the individual or the community by any outside influence; but the courts will protect an individual threatened by his neighbor, or a town whose health and comfort are menaced by the act of another town. The common law on the subject is clear and comprehensive; but the growing realization of the danger and the wantonness of stream pollution have led to special and stringent legislation in many of the States. Massachusetts, Ohio, New York, Minnesota and West Virginia were the pioneers in this work. Connecticut and New Jersey seconded them nobly.

In Pennsylvania, I am sorry to say, the bills intended to preserve the lives and the health of the people, by preventing the pollution of water-courses, have been invariably killed by the manufacturing interests, because, forsooth! it is cheaper to poison God's brooks and rivers than to remove or clean their own offscourings. What matters the sickness of the children, the death of breadwinners, if only the brute, commercial industry, is fed!

> " Thus they fling him, hour by hour,
> Limbs of men to give him power,
> Brains of men to give him cunning,
> And, for dainties to devour,
> Souls of children, little worth,
> Hearts of women, cheaply bought.
> He takes them and he breaks them,
> But he gives them scanty thought."

Perhaps you think I speak bitterly. But I know the iniquity; I have seen the harvest. I am now watching, with the gravest apprehension, a case where a State institution of the Commonwealth of Pennsylvania is pouring the sewage from nearly a thousand people into a stream which one can cross dryshod on stepping stones, while, less than two miles below, lies the water-intake of a town of considerable size. The sentiment of it all is disgusting enough; but one spark of typhoid at the institution above, one moment of carelessness on the part of the nurse in charge and—Heaven help that town!

Before describing the processes which enable us to dispose of our wastes hygienically, let us make sure that we understand what sewage is. Many people conceive it as a dark, turbid, foul-smelling liquid, the very incarnation of concentrated nastiness. As a matter of fact, *fresh* domestic sewage is almost clear, almost odorless and quite inoffensive. One can get a good idea of its appearance—and, what is more, a typical sewage for experimental purposes—by adding a tablespoonful of milk to a pail of water. Floating in this liquid are occasional solid particles of a hundred different kinds, yet strangely alike when their chemical constituents are considered.

Normal sewage contains, in a thousand parts, 998 parts of pure water, one part of mineral matter (largely salt), which is entirely harmless, and one part of dead organic matter. This last named item—insignificant in bulk, for it is but one-thousandth of the whole volume—is the only part that need be considered, for it alone is capable of mischief.

Organic matter is composed, practically, of three mineral elements—carbon, nitrogen and hydrogen—each inoffensive by itself or when combined with oxygen. These elements have been drawn from the soil by vegetation, and the vegetation, in turn, has perhaps been devoured by animal life and appropriated to the building up of its tissues. As these tissues are consumed in vital activities and replaced by fresh structure, they are discarded, and it is at this stage that they are delivered to the sewers.

Sewage also contains considerable vegetable tissue which is rejected (as in the preparation of food) without passing through an animal body. Its constituents and its destiny, however, are similar to those of the animal rejecta. Both are equally capable of causing offence or fostering disease.

In the conservation of matter, as of energy, nothing is ever lost. When a bit of organic structure passes from under the preserving control of the vital force, it must be demolished, and the materials of which it was built must be returned to nature's storehouse for further use. There is thus a constant, circling, interchange between the three physical kingdoms—animal, vegetable and mineral. If it were not so the supply of plant food would soon be exhausted, and life would perish, buried in its own refuse.

There is but one way in which organic matter can be disintegrated—by combustion. The ashes and gases which result from the combustion of animal or vegetable matter are no longer organic, but mineral. Combustion, which is but another name for oxidation, is of three kinds: Igneous, which we call fire; chemical, which is illustrated by the rusting of iron; and bacterial, which is commonly known as decay. The first can attack either mineral or organic matter. It is of little or no use in the treatment of sewage, for the one part in a thousand which we wish to destroy cannot be touched effectively by fire until the 998 parts of accompanying water have been evaporated, The second, chemical oxidation, attacks mineral matter only, save in a very limited degree. It is of no value in sewage treatment. The third, bacterial oxidation, is the means which nature has provided for the demolition of dead animal and vegetable tissue and the preparation of plant food.

Bacteria, as we all know, are minute living organisms, invisible as individuals, yet so numerous and so active as to balance the energy of all the constructive forces of the world. They are universally present in water, in the air, in the soil, and in our bodies. They have been at work ceaselessly since the first death of the simplest vegetable growth. Since the beginning of history they have disintegrated and returned to the soil a mass of human excreta, which alone would equal 178,000 pounds for each square foot of the earth's surface, to say nothing of the wastes of all other forms of animal life, and the enormous masses of dead vegetation. Manifestly, without their aid, existence would be impossible.

In the popular mind the word "bacteria" still calls up unpleasant pictures of dirt and sickness. The sensational press fosters this feeling, and keeps its readers nervous with tales—and sometimes with astounding pictures—of bacteria in bank notes, on car straps, in carpets and curtains. Patent-medicine vendors advertise their "microbe-killers," which fortunately are not so inimical to the welfare of mankind as their names would indicate. The truth is there are as many kinds of bacteria as there are kinds of men. Some few are known as the stimuli of certain specific diseases, but the vast majority are beneficent. The percentage of hostile forms is lower than the percentage of criminals in the total population; and no greater than the percentage of poisonous plants in the flora of the country. Wholesale germicide, because of the sins of the pathogenic individual bacterium, is as unjustifiable as wholesale homicide, because a criminal happens to be also a man.

There are many varieties of filth-destroying bacteria. Some of them work best without air; some are indifferent as to whether air be supplied or not; and to others air is a vital necessity. Those of the first class are more violent in their action than the others. Properly controlled, they are extremely useful, especially because they are able to break up and liquefy organic solids; but their activities must be directed and curtailed, for they belong to the class from which the criminal, disease-producing bacteria are recruited, and their products, if they are allowed unlimited sway, are foul and disgusting. They are the agents of *putrefaction*.

The air-loving bacteria, on the other hand, work without offence, and complete the mineralization of organic matter by combining its elements with oxygen. A familiar example of their action is the inoffensive decay and disappearance of the dead leaves in a forest. They are the agents of *decomposition*.

The bacterial destruction of filth is not accomplished in a single step. The unraveling of the inter-twisted strands is a complex process. One kind of germ breaks up the carbonaceous matters; another attacks and resolves the albuminoid ammonia; still another *begins* the oxidation of the free ammonia, but is unable to finish it without the aid of another group. The science of sewage disposal consists in the recognition of the progressive steps of decomposition, and the skilful use of the different groups of decomposing agents in series, so that each, in doing its own part of the work, may prepare the material for effective treatment by the next colony of helpers.

The practical application of these theories is exceedingly simple. The country house-wife who carries a panful of dish-water to her back-door and flirts it over the grass-plot is practising the art of sewage disposal as sanely and soundly as the expert engineer who devises complicated systems of tanks, airlocks, filters, siphons and the like, and then pump millions of gallons through them daily. The active agents and the successive steps towards purification are identical in both instances. The flirting of the dish-water scatters it, so that it strikes the ground, not in a mass, but in a finely divided condition—a film of inappreciable depth. This brings every part of it into intimate contact with air, and spreads it, more or less evenly, over a considerable area of purifying earth. The small solid particles of grease, food-refuse or free soap remain upon the surface, to be slowly oxidized by the bacteria which inhabit it, while the clarified water leaches away into the soil, running the gauntlet of untold myriads of organisms, which ransack every drop in search for food. Before it has gone very far, the water is practically pure; and a little later the retained solids have disappeared, passing off as carbonic acid, water, atmospheric nitrogen or oxidized nitrogen.

These conditions may be maintained indefinitely, if the water be not thrown too often in the same place. After each application, ample time must be allowed for the disappearance of all dampness, in order that air may penetrate the pores of the soil, supplying oxygen needed for chemical combination, and stimulating the air-loving bacteria. If the ground be allowed to become sodden, the air will be excluded from the soil, and putrefactive processes will speedily assert themselves.

This is the sum and substance of broad irrigation, which has been used, on a large scale, for many years with excellent results by Berlin, Paris and many other large cities. It requires a large area of porous, well-drained land; but, with this given, the cost of preparation is little and operating expenses light. If properly designed and cared for, the installation is permanent. We have in this country no fields commensurate in size or age with many in Europe; but we have excellent examples, on a small scale, of this method of disposal.

Where a sufficient area of suitable land, at a reasonable price, cannot be found, some steps must be taken to concentrate and intensify the purifying process, so that the same results may be obtained more quickly and in less space.

The first step made in this direction was the development of the process known as Intermittent Downward Filtration. This differs from irrigation only in that it employs a filtering medium so exceedingly porous and well drained that air can follow the descending sewage to a considerable depth. The zone of purification is thus extended downward and the capacity of a given area greatly increased. Occasionally beds of natural sand are found admirably suited for intermittent filtration; but any porous material will answer—gravel, broken stone, burnt clay, coke, coal, slag or shells. The purification depends, not upon mechanical straining out of impurities—though the word "filtration" might seem to indicate this, but upon the detention of the sewage, for a sufficient period, within a medium colonized with the purifying organisms and thoroughly aerated from time to time.

One common type of intermittent filter, known as the "contact bed," devised by W. J. Dibdin, late Chemist of the London County Council and Metropolitan Board of Works, consists of a pit (often a simple excavation in earth, but preferably lined with concrete or other masonry) filled with some coarse-grained substance like broken stone, coke, slag clinker, or even cinders—though the last named are hardly suitable because of their tendency to disintegrate. Each "unit" consists of a number of these beds—usually four or five—which are filled in turn, allowed to stand full for a while and then drained.

While the beds are standing full of stagnant sewage air is, of course, excluded, and oxidation is limited by the amount of oxygen *stored* in the bed or derived from the sewage itself. As the liquid subsides, air follows into the interstices of the filter and aerobic bacterial action is stimulated, sweetening the mass and storing a measure of oxygen for use in the next filling. The beds are filled and emptied (usually) but two or three times a day and the oxygen inhaled at each draining is but one-fifth the atmospheric contents of the voids, a trifling quantity as compared with the amount needed for the complete combustion of the impurities delivered to the bed. From the standpoint of bacterial economy the principle of operation is defective, for the different groups of bacteria, which should work separately and in sequence, are here huddled together, tenement-house fashion, regardless of their various needs and their mutual antagonisms. The nitrifying agents, which require abundant oxygen, and a food predigested to the point marked by the formation of nitrites, are periodically drowned by a sewage devoid of oxygen and strong in ammonias. As a result the purifying bacteria never attain the highest efficiency. The results are similar to those which would follow the labors of a farmer who stirred together oats, corn, clover, buckwheat and rye, and sowed the mixture broadcast.

For a while this contact-bed system enjoyed great popularity; but its shortcomings have been recognized, and at a recent meeting of eminent English engineers, the concensus of experience showed that "contact beds had not reached the high standard of purification which was once expected."

Far better is the type of filter drained at the bottom by an outlet never closed, and fed with sewage which comes into contact with all the surfaces of the filtering material without interfering with free aeration of the mass. The sewage evenly distributed at the top is never at rest, but is continually moving through the bed and always in one direction, so that each successive stratum becomes the abode of bacteria of a certain family, which are fed uniformly with food suited to their needs and which pass on, to the next group in the sequence, exactly the pabulum required for its sustenance. To carry out the simile, the oats, corn, clover, buckwheat and rye are now sown each in its own field, and the results are vastly better.

In 1894, it occurred to the late Colonel Waring that absorption of oxygen from the air was a somewhat slow process and that forced aeration of the filtering medium might hasten materially the work of purification. He accordingly established an experimental plant at Newport. Sewage from the main sewer was pumped into a series of tanks. These were filled, respectively, with coarse broken stone, fine broken stone, pebbles, quartz-gravel and coke; and an air-pipe, descending to the bottom of each, introduced a constant blast from a fan-blower. Three of the tanks were operated intermittently, and two of them continuously. In the latter, the flow trickled down in thin films over the particles of filtering material, while a blast from the blower rose continually through the voids between these particles. The results were unexpectedly good, and .the effluent was much purer than the Newport city water supply. It was collected in a square wooden tank, and in this we kept live fish. Since then the system has been introduced in many places. This system combines the maximum of purification with the minimum of land requirement. An area 8 feet square will purify 1,000 gallons of sewage a day. The operation of these filters involves the expense of running a fan-blower; but this is inconsiderable, especially if electric power, which needs little attention, be used.

All of the processes thus far described are based upon the theory that putrefactive action is to be avoided and decomposition alone employed. Indeed, until very recently, this theory was the very spinal column of the science of sewage disposal. A few years ago appeared what seemed to be a reversion to an old type—the septic tank, which has been called a "glorified cesspool." It was remembered that the old cesspools seemed to have a marvelous way of receiving, without any serious accumulation, solids amounting in volume to many times their own cubic capacity. This was well known but not understood. Investigation showed that many of the putrefactive bacteria have the power of liquefying organic solids. As these solids have always been more or less difficult to treat, the attempt was made to employ these useful but reprehensible bacteria, and it succeeded. Liquefaction, by anaerobic organisms, is to-day the cheapest and best means of treating the solids of sewage. Moreover, if properly controlled, the process is an admirable preparation for the subsequent oxidation of the dissolved impurities in aerated filters.

In its simplest form the septic tank, or digestion tank, as I prefer to call it, is simply a reservoir, with a capacity equal to the average flow of say twelve hours. The sewage, entering at one end, loses its velocity immediately, and its heavier suspended solids begin to sink, while the lighter rise to the top as scum. This separation of solids and liquid continues until practically all the suspended matter is eliminated. The clarified liquor then escapes gently at the far end of the tank from a plane between the sludge and the scum. This action continues from day to day, the solids accumulating until those which were first deposited, and attacked by the bacteria which colonize the tank, have become liquefied, passing out with the escaping effluent. Thereafter the rate of accumulation is exceedingly slow, for the process of liquefaction offsets the entrance of new solids.

The septic tank, however, must be carefully designed and carefully controlled. The capacity of the tank must be adapted to the volume of flow and means of adjustment provided. Depth must be sufficient to admit of ample sludge-storage and scum-formation, without encroaching upon the section of flow needed for complete subsidence. The current must be effectively checked at the very inlet and a distribution made that will secure the use of the whole cross-section of the tank; otherwise the sewage will pass through rapidly in stream lines while the sides or corners retain indefinitely festering accumulations. The clarified liquid must be withdrawn from the whole width of the tank in such a way that there shall be no considerable increase of velocity at the outlet. Means must be provided for the removal of silt without disturbing the general deposit of sludge. Light must be excluded; an even temperature must be maintained. The superficial area of walls available for colonization must be the maximum compatible with uninterrupted sectional flow. It is now believed best to construct a tank so that the velocity of flow will constantly diminish, thus securing a classification of the deposited solids. These, and other details with which I shall not burden you, must all be considered in designing a digestion tank.

The effluent from a tank of this kind is not pure by any means. It still contains practically all its original dissolved impurities, though their organic structure has been so shaken and loosened that subsequent purification by any of the processes already described is easy.

Realizing that, in many cases, high concentration of treatment is necessary, and yet the expense of running a blower almost if not quite prohibitive, an attempt was made some years ago to design a high-rate filter through which the sewage would pump its own air. This was successfully accomplished, and the "wave-bed" system is now in satisfactory operation in several towns. Each unit of a wave-filter consists of a long narrow bed, laid on a rather steep slope, preferably walled with masonry and floored with concrete, and filled to a depth of from 1 foot to 18 inches with crushed coke.

This coke is covered with a few inches of broken stone: (1) to hold down the lighter material and prevent washing, (2) to exclude the light, (3) to assist in maintaining an even temperature, (4) to hinder the theft of the coke for fuel, and (5) to present a sightly and uniform surface. The sewage never wets the stone, which always looks as though fresh from the crusher.

The liquid is fed to the head of each wave-bed intermittently, in measured doses, by a siphon, which delivers it faster than the coke can pass it.

By the time the flow of the siphon ceases, a head of water, equal to the depth of the coke, has accumulated at the upper end of the bed; and this passes down through the coke as a wave, flattening somewhat as it goes, but retaining its wave form until the bottom of the bed is reached. As the liquid travels through the coke, it drives out ahead of it all the exhausted air and gases of decomposition, and draws in behind it an equal measure of fresh air from the atmosphere. The bed is, in fact, a coke filter 100 feet deep (though laid on its side), no part of which is more than 18 inches away from the free atmosphere; and each succeeding wave pumps fresh air through its entire depth.

The passage of the liquid is so rapid that the purification is not so complete as in the forced aeration system; but it is amply good for all purposes save discharge into a drinking water supply. Our average results run from 84 to 93 per cent. of purification. Analyses made by the Ohio State Board of Health showed that the plant at Kenton accomplished over 94 per cent. of purification. A peculiar and admirable feature of this system is the oxygenation of the effluent to the point of saturation.

The success of either the contact-bed or the various forms of streaming filter depends largely upon the distribution of the sewage. The best method of distribution is undoubtedly hand-control; for the most ingenious mechanism cannot exercise judgment or perform its cycle of operation with the elasticity needed to meet perfectly conditions constantly varying. But hand-control is expensive, and elasticity of operation easily degenerates into irregularity of operation. So that it is usually wiser to trust an unsalaried, uncompromising mechanical device in preference to expensive human fallibility. Many complex arrangements of valves, floats, weights, gears, etc., have been devised; but all of these involve the employment of moving parts, and moving parts mean friction, wear, frequent inspection and attention and eventual renewal. Better, in my judgment, is distribution by means of siphons, airlocks and kindred devices, which consist solely of castings and piping firmly built into solid masonry and without valves or other moving parts. In mechanism of this class, the flow is controlled by air alone, and the air is transferred from one part of the apparatus to another, or released entirely by the rise and fall of the sewage in the several beds. By the automatic airlock device, sewage can be fed, in sequence, to any number of filters, and any filter once filled can be emptied after any determined interval. Moreover, any filter, or group of filters, may be cut out of the cycle, and the others will continue to operate in rotation. So long as there is sewage to be treated, the actuating power is present, and so long as the atmosphere rests upon the earth, the transmitting agent is ready to do its work. The castings and pipes, if properly painted, will last a generation.

Before closing I wish to say a word or two about the subject of location for sewage disposal works.

Fortunately, topographical conditions usually lead to location in a portion of the community low-lying, and therefore least desirable for residence. But if the works be well-planned, carefully built and *properly operated* there is no *hygienic* reason why they may not be placed in any convenient location.

If a sewage-disposal plant proves offensive, one of two things is certainly true—either the plant is defective or, what is more likely, the system is not cared for properly. The latter trouble is not uncommon, and it is usually due to a resurgence of the barbaric instinct that tries to throw away, without expense, what it does not want. I know of one town that built an excellent modern disposal plant, and then refused to vote $15 a month for its maintenance.

But, no matter what site is chosen, or how excellent the plant and how careful the attention given it, objections are to be expected—either from those who are willing to hinder public improvements by levying more or less open blackmail, or from those sincere, well-meaning folk who are governed by ill-founded fears or misguided sentiment. The fears may be banished by the exhibition of a single good plant; but the sentiment cannot always be dealt with so easily. No man cares to have his neighbors locate his house by saying: " He lives just across the street from the disposal works." But sentiment may be educated. One town not far from Philadelphia turned the landscape gardener loose on its disposal field. With stone walls he trained the brook in the way it should go; he built rustic bridges; he laid out paths, roads and flower beds; he graded, terraced and sodded. The grass is neatly trimmed, the paths are clean and well kept, and the tract is called frankly The Sewage Park. The entire town is proud of it, and with reason.

The surest index of a community's progress is the treatment accorded to its wastes. Wise is the man who recognizes the evils that threaten him, and takes efficient measures to avert them: but nobler is he who sees in threatening evil the possibility of future good; who knows that in things material as well as spiritual death is followed by resurrection.

Not long since I visited a town to inspect a sewage disposal plant of great interest. I was a stranger without a guide, but I followed the valleys of natural drainage, and these led me unerringly to the works I sought. As I stood on the road at the foot of the town, I saw in the valley below me a long roof which looked as though it might cover the sewage tank. Leaning on a gate near-by stood an old farmer, evidently a Scotchman, whose shrewd but kindly face betokened an interest in my movements. To make sure before descending that I was on the right track, I asked him if he could tell me for what purpose that long, low building was used. He sized me up for a moment before replying, and then said slowly: "It's full of unborn grass and flowers and fruit for God's garden." It was the best definition of sewage I had ever heard.

NOTE.—Mr. Hill exhibited lantern slides illustrating sewage disposal works at Rochester, Brooklyn, Napanoch and Depew, N. Y.; Willow Grove and Rosemont, Pa.; East Cleveland and Kenton, O.; Collingwood, N. J., etc., and described the various methods of construction employed.

A DIVISION OF TESTS ESTABLISHED BY THE SECRETARY OF AGRICULTURE.

The following special order has been issued by Secretary Wilson, of the U. S. Department of Agriculture, viz.:

It is hereby ordered, That there be, and there is hereby, established in the Bureau of Chemistry of the United States Department of Agriculture a Division to be known as the Division of Tests. The work of this Division shall be to test and investigate road materials and all materials of construction relating to agriculture, and to do collaborative work provided by law with other Departments which may require such assistance from the Secretary of Agriculture. This order is to take effect July 1, 1904.

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, November 16, 1904.

The Telegraphone.

BY DR. Z. B. BABBITT.

It affords me great pleasure to come before you this evening to introduce to your attention one of the great scientific discoveries of modern times—the telegraphone.

About four years ago an invention termed the "telegraphone" was announced, whereby it was possible to record and audibly reproduce telephone messages, and to erase such record without loss of record material. The basis of this discovery was surprising, as it proved to physicists that magnetism could be localized.

The discovery and invention was made by a Danish engineer, Valdemar Poulsen, of Copenhagen, Denmark.

To bring to your attention the primitive telegraphone, conceive a piece of steel wire, generally known as "piano wire," stretched between two points; take an ordinary electro-magnet and connect the coil of it in circuit with the secondary of an induction coil, the primary of which is in circuit with a microphone and battery. On speaking into the microphone, induced currents of electricity produce continuous variations in the field strength of the electro-magnet, and if we slide the electro-magnet along the steel wire, the magnetic fluctuations of the electro-magnet affect the steel wire in the form of variable magnetic intensities. There have been impressed on the steel wire undulations of magnetization, a kind of writing that is permanent and which faithfully records the articulations of the voice. If the coils of the electro-magnet are connected with the telephone receiver, and the magnet is made to travel over the steel wire again, the telephone receiver repeats what was spoken into the microphone; or, in other words, acoustic vibrations, analogous to the original vibrations of the microphone, are reproduced in the telephone receiver. A special feature of the telegraphone in its different forms is the ease with which the record may be erased, it being only necessary to saturate the steel wire with magnetism by drawing it in front of a more powerful magnet so as to equalize the magnetic level differences created by a record, the wire then becoming as susceptible to further records as it was before.

One of the first machines (the one which gained for Poulsen the medal at the Paris exposition in 1900, for original electrical research) consisted of a framework carrying a brass cylinder and a magnet-carrying device, so designed that the pole-piece of the magnet traversed the steel wire, about 1 millimeter in diameter, which is wound upon the cylinder in the form of a helix. The arrangement being, that the pole-pieces of the magnet shall rest upon the steel wire while the machine is recording, reproducing, or erasing. This machine had a length of time record of fifty seconds, being at that stage purely scientific. The space occupied by the machine was about 15 inches by 7 inches base and 7 inches high. It can readily be seen that as a commercial article it had no value, and that one of the first problems was to reduce the compass of the machine, this being done in various ways.

About a year and a half ago Mr. Poulson began using an arrangement analogous with mechanical phonographs. A polished cylinder of magnetical hard material and of similar dimensions as the well-known wax cylinders in use. The speed was about $\frac{1}{2}$ a meter per second, and the pitch of the screw about $\frac{3}{10}$ of a millimeter, or about $\frac{1}{80}$ of an inch. On account of these dimensions the pole of the magnet must be pointed. These cylinders gave good reproductions, adjacent lines showing no interference.

Mr. Poulsen, in a later form of apparatus, replaced these cylinders by steel disks about 4½ inches in diameter and about $\frac{1}{20}$th of an inch in thickness. The portability of these disks, the susceptibility of receiving records on both sides, the instantaneous erasure of records at will and the absolute secrecy of the subject matter of the record, lead one to believe it will, in the future, be a means of inter-communication superior to letter-writing. This machine weighs about 15 pounds, and is of about the same dimensions as the phonograph.

The most important step, however, in reducing the compass of the machine lay in the use of a smaller wire. The machine shown you to-night represents the latest type of telegraphone. The wire on it being only $\frac{1}{100}$th of an inch in diameter, has solved the question of length of record that can be made. This small machine has a time capacity of 30 minutes, and, as the length of record depends upon the length of wire used, it is simply a question of increasing the dimensions of these spools to give a time capacity of two or three hours.

This machine has the ability of performing five different functions, which, briefly stated, are as follows: (1) It receives dictations; (2) it reproduces to the dictator; (3) it reproduces to one at a distant point, the machine being under control at that point; (4) it records conversations between two persons over the commercial telephone lines without in any way interfering with the operation of those lines; (5) it records automatically, in the absence of the subscriber from the office, messages coming over the line during such absence, the machine being under the absolute automatic control from the ordinary performing function of the telephone line, the ringing of the bell starting the machine, the machine sending a signal over the line to the party talking, notifying him that the machine is running, the machine running a fixed length of time, sending another signal, then automatically stopping.

This instrument is of such a size as to permit it to be placed conveniently on a writing desk or a small table.

The wire runs between two pairs of magnets, placed horizontally on each side of it, at a speed of about 10 feet a second. The driving apparatus is a small electric motor, 110 volts, D. C., contained in the box. The record is effected by the action of the left-hand pair of magnets, facing you, the other pair of magnets being used for erasing.

The switch-box, as you see, is fitted with three press buttons, by which the recording wire can be run forward or backward or stopped.

As the erasing magnet is in operation when the wire is run forward, any portion bearing a record which is no longer required, can be utilized for a fresh record, the wire being cleaned by the erasing magnets immediately before entering the field of the recording magnets. It will be seen from this that the mere fact of making a record wipes out or erases any previous record on that part of the wire; this enables one, when dictating, to correct an error.

This other switch-box, as you see, is connected by a considerable length of cable to the machine, and is for the use of the typewriter in taking off dictation. This head piece enables the typewriter to hear the dictation. When used for dictation or recording direct the machine is spoken to through this transmitter. The machine is set in motion by the depression of the forward button in the switch-box, and the speaker having finished, the stop button is pressed.

The typewriter having taken as many words as he can memorize, depresses the stop-button, typewrites and repeats the process until the end. The motor does not stop dead, but reverses the running of the record for a few seconds, thereby enabling him to hear the last portion of the matter already heard. The other button enables him to run back as far as he wishes.

This application of the telegraphone dispenses with the services of a stenographer, and also leaves the principal free to dictate his letters at such intervals as may be most convenient to himself. It also provides absolute privacy to him, a fact not to be ignored, for a communication may be of such a nature that the presence of another person is sufficient to divert the mind.

Another type of machine is used for the telephone distribution of news, market quotations, music, etc. The reproduction is audible to any number of persons, whether present in one place or scattered over a wide area.

We think you will be interested to know that the King and Queen of England, during their recent stay at Copenhagen, visited the office of the Danish Telegraphone Company, where they remained for nearly an hour, and showed the keenest interest in this epoch-making invention of

Valdemar Poulsen. Speaking into the instrument, His Majesty said: "I am very much interested in having seen this wonderful machine, and feel sure it will be of great benefit and value."

Kelvin, Marconi, Silvanus P. Thompson, Alexander Graham Bell, Tesla, M. J. Garvey, A. W. Heaviside, Dane Sinclair and many others have given autograph letters of interest and approval of the invention.

What influence is the telegraphone destined to exert in human life?

The reproductions are true to the human voice either conversational or in song, and the day will come when every family will have records made at frequent intervals—from the child's first efforts at speech through an entire life; and families will prize these records as they do photographs; national bureaus will be established for the preservation of records of speeches of our public men and women; correspondence will be carried on by the use of the disk machine in preference to the present methods.

Many business transactions are carried on daily over the telephone, and the day is at hand when telegraphone records will be made of each and every transaction and filed away for reference. The telegraphone is destined to take the place largely of the present stenographer, and no business or professional man will think of writing his business letters, lectures or sermons.

The loud-speaking device, which is nearly ready for the market, reproduces sufficiently loud to fill a lecture hall, and makes it not only possible, but probable, that the telegraphone will play an important part in the entertainment field.*

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* At the close of the meeting a demonstration was made of the operation of the telegraphone.

THE BROWN WIRE-WOUND GUN TESTS.

The tests of the 6-inch Brown segmental wire-wound gun, 50 calibers long, now going forward at the Government proving grounds at Sandy Hook, are said to have been so successful that it is claimed a new world's record for heavy ordnance is assured. The Board of Ordnance and Fortification some months ago made an allotment of $41,000 to build and test one of these guns with 250 rounds of ammunition. The New York *World* states that six rounds have already been fired. The initial round, with 32 pounds of powder, produced an initial velocity of 1,913 feet per second. The weight of the charge was increased thereafter, until with 64 pounds of powder a velocity of 3,178 feet per second was obtained, with a pressure of 33,450 pounds per square inch. The tests, which are made with smokeless powder, will be continued until 250 rounds have been fired. The velocity attained with the charge in the test of December 7th already establishes a new world's record for this type of gun. It is expected that a velocity of 3,500 feet per second will be attained with a pressure of from 43,000 to 45,000 pounds per square inch. It is stated that the gun will safely withstand the above pressure of 45,000 pounds per square inch, and that consequently the velocity of 3,500 feet per second, which will establish a new world's record, is assured.

RAPID ADVANCES IN RUBBER.

Manufacturers of articles in which rubber is used are confronted by radically increased costs on the raw rubber. Notwithstanding the fact that the production of rubber is increasing rapidly each year, the increase in consumption is in a ratio so much larger that prices are mounting skyward, and there is no little danger of an actual shortage. The highest price for pure Para rubber in 1880 was 50 cents per pound. The average price from 1885 to 1892 was 76 cents. The price in March, 1902, was $1.02. The price November 1, 1904, was $1.13, and prices quoted the past week range from $1.30 to $1.32½. These prices are all f.o.b. New York in car lots. At no period since rubber has been a large commerciol commodity have price-increases been as startling as during the last few months. During the month of November a total of 14 cents was added to the wholesale prices.

There are a number of natural reasons for this increase in the price of rubber apart from whatever manipulation may be present in the market. The small item of rubber heels to shoes has consumed quite a tonnage. Automobile tires call for the purest rubber in a larger proportion compared with adulterants and fabric than in most other arts. The widespread use of rubber tires for carriages and other vehicles consumes to-day a greater tonnage than the total importation of rubber twenty years ago. It is estimated that last winter no less than 60,000,000 pairs of rubber boots and shoes were manufactured and sold. The rubber industry is daily assuming larger proportions and greater importance, and rubber is finding its way into a countless number of manufactured products in which it was not used some years ago. The rise in the price of raw rubber is therefore quite in line with the progress of the industry.—*Iron Age.*

The Effect of Preservatives on Health and Digestion.*

By H. W. Wiley, M.D.,

Chief of the Bureau of Chemistry, U. S. Department of Agriculture, Professor of Agricultural and Hygienic Chemistry, Franklin Institute.

The question of the use of preservatives in food products is one of foremost importance. Not only is it a question which concerns the public health, but also one which concerns the character of commerce.

That food must be preserved is self-evident. It would not be possible nor desirable that every food should be consumed the moment it is ready for consumption. The various industries in which humanity is engaged, the development of means of transportation which bring all climates and all countries together, the use of food in long voyages of discovery, in mining camps, in the army and navy, as well as its general use in many other instances, make it necessary that it should be preserved.

Many foods, and those of the most important character, are self-preserved—for example, the cereals, nuts, ripe beans and peas. Other forms of food are preserved naturally for a greater or less length of time, such as fruit, berries, eggs and meats. Still other forms of food begin to decay soon after they are perfected; fish and oysters are types of this character of food.

Modern civilization demands that food shall be manufactured and preserved and made more or less ready for use. In these processes, from the earliest times well-known methods of preservation have been practised. The removal of water from a food product is a method of preservation which has been practised from the earliest times. The use of certain condimental substances, such as salt, sugar, vinegar and wood smoke, has also been practised from the earliest periods of history for preservative as well as condimental purposes. During the last hundred years the sterilization of food by heating and the exclusion of the germs therefrom have been practised on a large scale and is still one of the safest and most approved methods of preservation.

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* A lecture delivered before the Franklin Institute in Association Hall, Philadelphia, Friday, November 4, 1904.

Since the development of the method of making artificial cold, cold storage has played a very prominent part in preserving food products. It may be said that no reasonable objection can be made to any of the above processes provided they are conducted in a rational way and for a reasonable length of time. For the past fifty years, however, there has grown up a system of food preservation based on the use of so-called antiseptics, that is, chemical products which of necessity must be colorless and without taste or odor and which have the power of paralyzing or destroying the fermenting germs which cause food to decay. It is this class of preservatives to which attention is directed at the present time. The more common of these are well known, such as boric acid, borax, salicylic acid, benzoic acid, sulphurous acid, formaldehyde, etc. Concerning the use of these bodies the greatest difference of opinion prevails. Many manufacturers and a number of physiologists and chemists claim that the use of these bodies is in no way detrimental and that their use should not be restricted. There is another large class of experts who claim that the addition of such antiseptics to food is reprehensible and that their use should be restricted or even prohibited.

It was for the purpose of determining these points of difference between experts that the experimental work of the Department of Agriculture on food preservatives was undertaken. The results of one series of experiments of this kind have been collated and are almost ready for publication.

In these experiments borax and boric acid were added to food, beginning with small and gradually increasing to large doses per day. The small doses were ½ gram (7½ grains) and the large doses were from 3 to 4 grams (45 to 60 grains) per day. These experiments were carried on during a period of about nine months and the results which were manifested are as follows:

Boric acid and borax in gradually increased doses, with a maximum of from 3 to 5 grams per day, cause a disturbance of digestion and health manifested in loss of appetite, a loss of weight, a feeling of uneasiness and sometimes of illness in the stomach, a fulness in the head which often developed into a dull and persistent headache, a general disturbance of the metabolic functions of digestion and many other disturbances which were of a markedly unfavorable character.

When borax and boric acid are administered in small doses, namely, ½ gram (7½ grains) per day over a long period of time, similar symptoms in a less acute form are developed in the majority of cases. In one instance, where small quantities of borax were given for fifty days, there was a gradual but not pronounced loss of weight, a gradual and, in some cases, pronounced failure of appetite, a somewhat well-developed feeling of uneasiness in the stomach and a dull but persistent headache, all of which symptoms disappeared within a period of ten or fifteen days after the administration of the borax was discontinued.

In the consideration of the action of preservatives of a mineral nature, such as borax and boric acid, it must be remembered that the animal, as well as the plant, possesses a certain mineral hunger. In other words, mineral substances play a double role in animal and plant nutrition. First, they may serve as real food, necessary to the formation and nutrition of the tissues. In the second place, they are necessary to the functional activity of the various organs of the body, irrespective of any part they may take in direct nutrition.

The necessity of saline solutions in the blood is known to every physician and physiologist. If the blood were deprived of all of its saline constituents, the circulation would be impeded, restricted or stopped, and death would result. In cases of collapse in disease saline injections in the blood are often used as a restorative measure. These salts in solution stimulate the heart's action, and undoubtedly are active in the osmotic operations of the cells. This is one of the facts which show the intimate relation existing between physical chemistry and physiology.

Common salt is the most frequent and most abundant of the saline constituents of the blood, but the alkalinity of the blood is not due, of course, to common salt, which is a neutral substance. The existence of alkaline carbonates or other alkaline salts is necessary to the vital functions. While it is true that the digestion in the stomach takes place in an acid solution, it is likewise true that any excessive acid must be neutralized and enough of alkali added in the small intestine, in order that the further digestion of the food may properly take place. That saline bodies other than common salt or the alkaline carbonates may be useful, however, in the performance of the vital functions cannot be denied, though it might be difficult to demonstrate their absolute necessity. Hence the introduction of saline bodies, which may or may not be of an antiseptic character, may, within certain limits, have a favorable influence upon health and digestion. At the same time it should not be forgotten that all excess of such bodies imposes upon the excretory organs an additional burden, which, while it might not impair their efficiency even for a number of years, might finally induce a condition of exhaustion which would be followed by serious consequences. Especially is this remark true of the kidneys, which appear to be a general clearing-house for all the surplus of saline matters ingested in the foods.

Are Minimal Quantities of Preservatives Permissible?—It is admitted by all who have examined the subject in a critical way, even by the users of preservatives, that in certain máximum quantities the limit of toleration is reached in each individual and positive injury is done. But it is also well recognized that many, if not all, of the usual foods when used in large excess produce injurious results. The many cases of disease produced by overeating, or by eating improperly prepared or poorly cooked foods, or by eating at unusual times, are illustrations of this fact. Upon this basis and upon the further statement that, when used in extremely small quantities, the preservatives in question cannot be regarded as harmful, is founded the principal argument in favor of the use of the preservatives, aside from the fact that the foods themselves are kept in a better and more wholesome state.

It is only proper to give to this argument full consideration and not to brush it aside as illogical and irrelevant. It is evident that any attempt to determine experimentally the effect of extremely minute quantities of any preservative, even when used continuously, would not be likely to lead to any definite result. In the foregoing data we have illustrations of the fact that even large quantities of the preservative employed—larger by far than would probably ever be found in any food product—do not always act in such a way as to permit of definite interpretation. The claim, therefore, that the use of such preservatives is justified when the amount is extremely small, and when even these small amounts are used only at intervals, and not continuously, is worthy of careful consideration.

An illustration which is pertinent may be taken from the particular preservatives with which the foregoing experiments have been made, namely, boric acid and borax. One of the food products to which these preservatives are very commonly added is butter. This statement should not be taken to imply that in butter prepared for domestic use in this country borax is found to any considerable extent. When butter, however, is to be transported over long distances, and necessarily kept a long while, the addition of borax is very frequently practised.

The dietetic data which have been accumulated in the course of this experiment show that the quantity of butter consumed daily varies from 30 to 70 grains. Suppose, as a maximum, we say that the quantity of butter consumed in any one case daily is 100 grams, and that it contains 1 gram of boric acid, or an amount of borax equivalent thereto. The maximum quantity of boric acid used in a day in this case would be 1 gram. In point of fact, however, it would rarely, if ever, reach this amount, but even in those cases where butter is eaten freely probably half a gram would be about the maximum quantity consumed. Further than this, 1 per cent. of boric acid, or its equivalent in borax, in butter is a very large quantity. Probably, as a rule, not more than one half of 1 per cent. is employed. In this case the quantity of boric acid likely to be consumed by any one individual in a day would be reduced to one-quarter gram.

In the case of meats preserved by borax, although larger quantities are eaten than of butter, it is not likely that any larger quantities of borax would be consumed. Thus it appears that those who habitually eat butter and meat preserved with borax might be consuming half a gram or a little more of boric acid per day. But preserved meats are not regularly eaten, and hence the quantity mentioned is likely to be overestimated. It would be unwise to affirm in a case of this kind, in the light of the data obtained by the experiments, that such a minimum consumption of borax, and especially when not a continuous one, would prove deleterious within any reasonable time of observation. The question then arises, Does the absence of such proof or the impracticability of obtaining it serve as a justifiable excuse for the use of this preservative?

This question ought not to be decided alone, because the principle of the decision must stand, not only for boric acid and borax, but for every preservative used in foods. In other words, whatever principle is established for judgment as to the use of boric acid in small portions must also be applied to the use of every other preservative used in foods. The principle must also be still further extended, so that whatever may be established as regards butter or meat must be admitted in respect of every other substance used in food. Hence, before admitting the full force of the argument based on minimal quantities, the full significance of such an admission must be considered and the practically unlimited extent of its application acknowledged.

This leads to the discussion of the fact that in the majority of cases the labor of freeing the system from added preservatives falls principally upon the kidneys. In the method of life in vogue in this country the kidneys are already hard-worked organs. Americans probably eat more freely than the citizens of almost any other country, with the possible exception of England. Large quantities of nitrogenous foods are consumed. In the breaking down of the nitrogenous tissues the kidneys are the chief organs for the excretion of the debris. The addition of any further burden, therefore, no matter how minute, is to be deplored. If, however, the principle be admitted that injurious substances may be used in such small quantities as to be practically harmless, then we find the way open for loading upon the kidneys many different functions in addition to those which they now discharge. If they may be justly called upon to eliminate the small quantities of boric acid added in food, they can not logically be freed from the necessity of eliminating also minute quantities of salicylic acid, saccharin, sulphurous acids and sulphites, together with the whole list of the remaining preservatives, which are eliminated principally through the kidneys. It would be useless to contend that the occasional consumption of small quantities of boric acid in a sausage, in butter, or in preserved meat would produce even upon delicate stomachs any continuing deleterious effect which could be detected by any of the means at our disposal, but naturally it seems that this admission does not in any way justify the indiscriminate use of this preservative in food products, implying, as it would, the equal right of all other preservatives of a like character to exist in food products without restriction.

It appears, therefore, that there is no convincing force in the argument for the use of small quantities unless it can be established that there is only a single preservative used in foods, that this preservative is used in only a few foods, that it will be consumed in extremely minute quantities, and that the foods in which it is found are consumed at irregular intervals and in small quantities. On the other hand, the logical conclusion which seems to follow from the data at our disposal is that boric acid and equivalent amounts of borax in certain quantities should be restricted to those cases where the necessity therefor is clearly manifest, and where it is demonstrable that other methods of food preservation are not applicable and that without the use of such a preservative the deleterious effects produced by the foods themselves, by reason of decomposition, would be far greater than could possibly come from the use of the preservative in minimum quantities. In these cases it would also follow, apparently, as a matter of public information and especially for the protection of the young, the sick and the debilitated, that each article of food should be plainly labeled and branded in regard to the character and quantity of the preservative employed.

Borax and boric acid are regarded by most experts as the least harmful of the antiseptics usually employed. Whether this is a true view of the matter or not remains to be determined by subsequent experiments. It is evident, however, from the results of experimental work that the miscellaneous and premeditated use of these antiseptics in food is reprehensible. There may be occasions when the use of borax is advisable, as, for instance, where butter must be shipped many thousands of miles before it is used or where meats are to be sent across the ocean, and perhaps in various other instances which render imperative the use of a preserving agent. It follows, therefore, that foods should only be preserved with a view to special use. When they are intended for consumption within a short time and for the ordinary continuance of life, it does not seem necessary that any antiseptic should be used, as the food can be perfectly preserved by unobjectionable methods in some of the ways indicated above. Where foods are prepared for various purposes, such as long journeys, excursions, voyages of discovery, etc., as indicated above, it appears that borax could be employed properly if its use is demanded by those who order the food, and if the food products are plainly labeled as having been preserved by this substance. It is, moreover, evident that eating small quantities of borax in food, occasionally, would not prove of any lasting injury to the ordinary citizen in good health, but the weak and feeble must be protected, and it is entirely within the grounds of reason that even a very small quantity of an antiseptic of this kind would prove very harmful to a disordered stomach.

The safest rule, therefore, to follow is to exclude these bodies from food except when their use is imperative, and then the quantity of the antiseptic employed should be plainly stated in such a way that the consumer may know what he is eating.

Similar experiments to the above have been conducted with salicylic, benzoic and sulphurous acids, but the results of the experimental work have not yet been compiled nor have the conclusions been drawn. This work is to be continued during the coming year, when it is our purpose to determine the effects of formaldehyde and coloring matter, when added to food, upon health and digestion.

The Value of the Flame of Combustibles.

BY P. MAHLER,
Civil Engineer of Mines.

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BY B. F. ISHERWOOD,
Chief Engineer, U. S. Navy.

I. Value of the Flame of Combustibles.

The calorific power and the chemical composition are, in general, sufficient elements of comparison between natural combustibles. These data permit, notably, the calculation of the value of flames, and the question may be asked whether this calculation has any practical utility.

The value of the flame of a combustible is the same thing as its temperature of combustion under constant pressure. It is measured by the thermometric degrees through which the gaseous products of the combustion are raised, supposing them to be heated by all the heat due to the combustion and solely by that heat. It must also be admitted that the combustion is complete and that it is realized by the aid of air under the atmospheric pressure, always nearly constant, as it takes place on grates.

The preceding definition is in accord as much as possible with industrial conditions; but, in fact, the temperature of combustion is a theoretical number defining with precision a limit that practical industry cannot exceed with any given combustible and for the given bodies to be heated; and it seems interesting to compare different coals from this point of view.

The calorimetrical bomb and the elementary analysis having supplied* me with the necesary data for the calculation of temperatures of combustion, I have determined the value of the flames of a complete series of combustibles.

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* "Etude sur les Combustibles," by P. Mahler, 1903, published by Beranger.

II. Determination of the Temperature of Combustion.

The determination of the temperature of combustion is done without difficulty, and the method I have followed is an old one. Nevertheless, I will cite the principal points because they can be of service to engineers in many cases, as in the examination of the functioning of furnaces,* and of the economic results of gas-motors calculated from the temperature of detonation of an explosive, etc.

Be q the calorific power of unit of weight of a combustible under constant pressure. Be C_m the mean specific heat† between O and T, absolute temperature of any one of the gases whatever composing the gases of combustion; let it be taken in relation to the weight of the gas which occupies a volume equal to 22·3 liters. Be N the number of molecules (22·3 liters) of this gas resulting from the combustion. As the energy of a gaseous mass depends wholly on its temperature, and as the coal in question is burned at a temperature very near 0° C. or T_0, the heating due to the combustion between T_0 and T_1 is, according to our hypothesis, united closely to the calorific power by the expression

$$q = \Sigma N(C_m T_1 - C_m T_0),$$

Σ signifying that the gases of combustion are a mixture of several gases for which N and C_m have special values.

The analysis of the combustible gives N, and if C_m were constant, we could easily deduce from the above equation T_1, since the temperature sought for $\theta = T_1 - 273°$ in Centigrade degrees.

But the problem is more complex. Messieurs Mallard and Le Chatelier have demonstrated that the specific heat of the gases of combustion increase with their temperature, this phenomenon becoming very sensible at high tempera-

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* "Le Chauffage Industriel," by Mr. E. Damour.

† dq being the elementary heating of 1 kilogramme, the true specific heat at the temperature t is

$$\frac{dq}{dt} = c$$

by definition.

Between the true heat and the mean heat from o to t, we have, in general, the relation:

$$S_o^t \, cdt = Cmt, \quad c = \frac{dC_m t}{dt}.$$

tures. According to these physicists, it should be represented by a function

$$C_m = \alpha + \beta T.$$

The calculation of T_1 and, consequently, of θ, depends then on an equation of the second degree:

$$q = \Sigma N \left[(\alpha + \beta T_1)\, T_1 - (\alpha + \beta T_0)\, T_0 \right]$$

$$q = \Sigma N \left[\alpha (T_1 - T_0) + \beta (T_1^2 - T_0^2) \right] \qquad (1)$$

Messieurs Mallard and Le Chatelier have deduced from their experiments the values of α and of β relative to the different gases.*

I ought to say that in these later days, certain very exclusive partisans of the law of Clausius regarding specific heats, have contested the law of increase shown by Messieurs Berthelot and Vieille and by Messieurs Mallard and Le Chatelier. The law of increase, nevertheless, does not for this reason appear any less conformable to the truth. And if we reflect on the considerable difference existing between the temperatures of combustion calculated according to this law and the highest temperatures obtained in the best industrial furnaces (Martin-Siemens' furnace, 1,600°), we may even suppose—for the effect of the dissociation is feeble—that the increases resulting from the known experiments, are inferior to the truth.

Under any circumstances, the exactness of the experiments of Messieurs Mallard and Le Chatelier certainly surpass the precision I need for the comparative investigation that is the subject of this note.

Which being premised, we will now return to the calculation of the temperature of combustion of coals and of other natural conbustibles.

The gases of combustion comprise in general only perfect gases such as azote, and incidentally the oxide of carbon, and the condensed gases steam and carbonic acid. Relatively to the perfect gases, the remark must be made that their specific heats are nearly equal at all temperatures between the ordinary atmospheric temperatures and the temperature 3,000.°

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* Researches, experimental and theoretical, on the combustion of explosive gaseous mixtures; third memoir on the temperatures of combustion and the specific heats of gases at high temperatures, by E. Mallard and H. Le Chatelier ("Annales des Mines," 1885).

Report on the study of the questions relative to the use of explosives in presence of grisou (fire damp); temperature of detonation; by E. Mallard ("Annales des Mines," 1888).

According to the above physicists, the following are the coefficients for the above gases.*

$$\text{Perfect gases}\quad\begin{cases}\alpha = 6{\cdot}5 \times 1{,}000^{-1}\\ \beta = 0{\cdot}6 \times 1{,}000^{-2}\end{cases}$$

$$\text{Superheated steam}\quad\begin{cases}\alpha = 6{\cdot}5 \times 1{,}000^{-1}\\ \beta = 2{\cdot}9 \times 1{,}000^{-2}\end{cases}$$

$$\text{Carbonic acid}\quad\begin{cases}\alpha = 6{\cdot}5 \times 1{,}000^{-1}\\ \beta = 3{\cdot}7 \times 1{,}000^{-2}\end{cases}$$

From these result the following expressions of the heating of a molecule of the above gases from T_0 to T_1 in large calories.†

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* "Cours de Chimie Industrielle," by H. Le Chatelier.

† There may be needed the expression of the heating of a constant volume; for example. for the calculation of the temperatures of detonation, and also for the study of gas-motors.

In this case, the coefficients of $[T_1^2 - T_0^2]$ are the same as above, and the coefficient of $[T_1 - T_0]$ is solely

$$4{\cdot}5\,\frac{T_1 - T_0.}{100}$$

There may be also need of the heating of a molecule of methane, as follows:

$$4{\cdot}5\,\frac{T_1 - T_0}{1000} + 6\,\frac{T_1^2 - T_0^2}{1000}$$

at constant volume.

The difference between the heating at constant volume results from the difference between the two specific heats $[Cp, Cv]$ a difference due to the quantity of heat absorbed by the work of dilatation accompanying the increase of temperature.

We know, in fact, that the two heats of the heating are connected by the expression:

$$q = Q + A\int_{v_0}^{v_1} p_0\,dv, \text{ or } q - Q = A\int_{v_0}^{v_1} p_0 dv.$$

Taking account of the equation $pv = RT$ and the definitions of Q and of q, there exists between the two specific heats at constant pressure and constant volume.

The values of the heating of one molecule of gas and the knowledge of the numbers N of molecules disengaged by the combustion, enables us to translate into figures the equation (2). Further, this equation will give directly the heat of combustion sought for in degrees Centigrade; if we put

$$T_0 = 273; \ T_1 = \theta + 273,$$

it becomes then

$$q = \Sigma N \left[\frac{a\theta}{1000} + \beta \frac{(\theta + 273)^2 - 273^2}{1000^2}\right]$$

in large calories, and we can solve it algebraically. But when we have to determine a great number of temperatures, as in this investigation, it is preferable to employ the following artifice:

Briefly, it consists in finding a positive value of θ, so that the number of calories expressed by Σ equals the number of calories q of the calorific power.

Arrange then the table of the heating of one gaseous molecule from 0° to 100, 200°C., etc., from 100 to 100° for example. Extend the Table to the perfect gases, to superheated steam, and to carbonic acid. This operation is easy by means of the formulas we have given. Further, the calculation can be very rapidly made; the squares

$$[T + 100]^2, [T + 200°]^2, [T + 300°],$$

etc., are immediately deduced, one from the other.

$$(Cp - Cv)\,(T_1 - T_0) = Ap_0\,(v_1 - v_0) = \frac{Ap_0\,v_0}{273}\,(T_1 - T_0)$$

or between the molecular heats:

$$Cp - Cv = \frac{Ap_0\,v_0}{273}$$

Taking as units the kilogram and the decimeter:

$$A = \frac{1}{E} = \frac{1}{4260}, \quad p = 103{\cdot}33, \quad v_0 = 22300, \quad Cp - Cv = 1{\cdot}98$$

about two calories.

Perfect gases, $q = 6{\cdot}5\,\frac{T_1 - T_0}{1000} + 0{\cdot}6\,\frac{T_1^2 - T_0^2}{1000^2}$

Superheated steam, $q = 6{\cdot}5\,\frac{T_1 - T_0}{1000} + 2{\cdot}9\,\frac{T_1^2 - T_0^2}{1000^2}$

Carbonic acid, $q = 6{\cdot}5\,\frac{T_1 - T_0}{1000} + 3{\cdot}7\,\frac{T_1^2 - T_0^2}{1000^2}$

The numbers N, on the other part, being known, it is very evident that the table in question enables the value of the total heating of the residue of combustion (azote, carbonic acid, superheated steam), corresponding to 100, 200°C., etc.

Also, as we have always an idea approximately of the temperature sought for, it suffices to calculate the value of Σ for temperatures near θ, in order to determine the quantities of heat q_1 and q_2, such as

$$q_1 < q < q_2$$
$$\theta_1 < \theta < \theta_1 + 100.$$

The temperature sought for is comprised between θ and $\theta_1 + 100$, it differs from θ_1 by a quantity E, $\theta = \theta_1 + E$. Now E is easily calculated with sufficient precision.

In fact, between θ and $\theta_1 + 100$ there can be admitted that the increase of the temperature is proportional to the increase in the quantity of heat, and that, in this interval, 1 calorie corresponds to an augmentation of temperature:

$$\frac{100}{q_2 - q_1}.$$

E, which corresponds to an increase of heat $q - q_1$, is, under these conditions, represented by

$$(q - q_1) \frac{100}{q_2 - q_1}$$

and the approximate value of θ is

$$\theta = \theta_1 + (q - q_1) \frac{100}{q_2 - q_1}.$$

The solution is not rigorous, but a greater exactness is useless.

A further reproach to this method of determination is that it does not take into account the dissociation of the superheated steam and of the carbonic acid. Regarding this objection, however, there may be stated that the dissociation of the superheated steam between 0° and 2,500° has a negligible influence. The effect of the dissociation of the carbonic acid is, also, practically but little sensible up to 2,000°, a temperature near which are grouped the most part of the numbers that I give later on. Two of these numbers are near 2,500°, and it is proper to say that the coefficients of dissociation of the carbonic acid seem to have a real importance in the neighborhood of that temperature.*

Table of the Heatings in Calories.

The table of the heatings of the molecular volume of the gases is a useful document for many purposes. I think it beneficial to publish the one which I have used; its figures

HEATINGS IN CALORIES OF THE MOLECULAR VOLUME OF GASES FROM 0° C. TO 3,000° C. (UNDER CONSTANT PRESSURE.)

The molecular volume corresponds to 22·32 liters. The molecules are represented by the symbols Az^2, O^2, H^2, CO, CO^2.

Temperatures.	Azote, Oxygen, Oxide of Carbon, Hydrogen.	Superheated Steam.	Carbonic Acid.	Temperatures.	Azote, Oxygen, Oxide of Carbon, Hydrogen.	Superheated Steam.	Carbonic Acid.
0° C.	0·00	0·00	0·00	1,600° C.	12·46	20·35	23·09
100	0·68	0·83	0·87	1,700	13·34	22·13	25·18
200	1·39	1·73	1·85	1,800	14·23	23·93	27·31
300	2·10	2·67	2·87	1,900	15·14	25·83	29·55
400	2·82	3·69	3·99	2,000	16·05	27·76	31·83
500	3·56	4·76	5·17	2,100	16·98	29·74	34·18
600	4·31	5·89	6·44	2,200	17·92	31·81	36·64
700	5·07	7·07	7·77	2,300	18·87	33·91	39·14
800	5·85	8·30	9·16	2,400	19·84	36·10	41·75
900	6·63	9·62	10·06	2,500	20·81	38·32	44·40
1,000	7·43	10·98	12·12	2,600	21·80	40·62	47·16
1,100	8·24	12·40	13·85	2,700	22·80	42·95	49·96
1,200	9·05	13·87	15·55	2,800	23·82	45·37	52·87
1,300	9·89	15·41	17·33	2,900	24·84	47·82	55·81
1,400	10·73	17·00	19·18	3,000	25·88	50·35	58·86
1,500	11·59	18·65	21·11				

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* The coefficient of dissociation is the proportion of the gas dissociated to that which would exist if the decomposition were complete. For carbonic acid, and at 2,500°, these coefficients are approximately 0·2 (pressure of 1 atmosphere), 0·4 (pressure of $\frac{1}{10}$ of an atmosphere), etc.

See Experimental Researches on Chemical Equilibriums, by Le Chatelier, "Annales des Mines." 1888.

have been carefully collated, and it is more extensive and nearer complete than the most part of those heretofore published.

III. Examples of Determination of Heats of Combustion.

Our hypotheses suppose that the combustibles are burned under the normal atmospheric pressure and with the aid of air, at the temperature of 0° C.

One hundred volumes of air decompose into about 80 volumes of azote and 20 volumes of oxygen. Consequently, if a molecular volume of oxygen, O^2, is necessary for the burning of a certain combustible, the gas resulting from the operation will comprise, specially, 4 molecular volumes of azote or $4Az^2$.

In order to commence, take the simplest case, that of the combustion of hydrogen.

(1) *Temperature of Combustion of Hydrogen.*—According to the above conventions, the combustion of hydrogen in cold air will be expressed as follows:

$$H^2 + \frac{O^2}{2} + 2Az^2 = 2Az^2 + H^2O, \text{ gas, } + 58{\cdot}2 \text{ calories.}$$

The residue of the combustion of 1 molecule (or 2 grams) of hydrogen comprises, then, 2 molecules of azote and 1 molecule of vaporized water. The heat disengaged by the reaction is 58·2 calories $= q$.

By referring this to the table of molecular heatings, there are easily obtained the values of Σ at about the anticipated temperature θ of combustion.

Heating at	1,800°	1,900°	2,000°
Of 2 molecules of azote,	$2 \times 14{\cdot}23 = 28{\cdot}46$	$2 \times 15{\cdot}14 = 30{\cdot}28$	$2 \times 16{\cdot}05 = 32{\cdot}10$
Of 1 molecule of steam,	$= 23{\cdot}93$	$25{\cdot}83$	$27{\cdot}76$
	$52{\cdot}39$	$q_1 = 56{\cdot}11$	$q_2 = 59{\cdot}86$

The temperature sought for is, then, between 1,900° and 2,000° C., corresponding respectively to the heatings in calories 56·11 and 59·86. Finally, we have, by applying the formula established above and taking account that $q = 58{\cdot}2$ calories,

$$\theta = 1900 + (q - q_1)\frac{100}{q_2 - q_1} = 1900 + 2{\cdot}09\,\frac{100}{3{\cdot}75} = 1956^\circ \text{ C.,}$$

or, in round numbers, 1960° C.

We should find for the oxide of carbon, very approximately, 2,100° C., the flame of oxide of carbon is, then, hotter than the flame of hydrogen.

(2) *Temperature of the Combustion of a Peat.*—Analysis of 100 grams of the specimen remaining after abstraction of ash and hygroscopic water:

Carbon	57·21
Hydrogen	5·69
Oxygen and azote	37·10
	100·00

Calorific power, water vaporized, 5,590 calories, corresponding for 100 grams to 559 calories.

The gases resulting from the combustion of 100 grams, in air, of this peat, comprise carbonic acid, water vaporized, and azote, of which the above analysis permits the determination of the number N of molecular volumes.

The proportion of carbonic acid is deduced from its tenor in carbon; as we know that 12 grams of carbon give, in burning, a molecular volume of carbonic acid, there will be in the gases of combustion

$$\frac{57{\cdot}21}{12} = 4{\cdot}76$$

volumes of carbonic acid.

Similarly, since 2 grams of hydrogen produce a molecule of water, the proportion of water vaporized will be

$$\frac{5{\cdot}69}{2} = 2{\cdot}84$$

volumes.

To calculate the azote, it is necessary to proportion it to the quantity of oxygen strictly utilized for the combustion.

	Volumes of Oxygen.
Now with 4·76 volumes of carbonic acid there are combined	4·76
And with 2·84 volumes of water vaporized there are combined	1·42
Total	6·18

Deducting from this sum the corresponding volume of oxygen pre-existing in the peat

$$\left(\frac{37{\cdot}10}{32} = \right) 1{\cdot}16,$$

and neglecting the small quantity of azote which accompanies this body in the peat, it becomes 6·18 — 1·16 = 5·02, or about 5 volumes. Five molecular volumes of oxygen are then necessary to burn the peat in question; these 5 volumes correspond to 25 volumes of air containing 20 volumes of azote which pass unchanged into the gases of combustion.

To sum up: The residue of combustion will have the following composition in molecular volumes:

Azote	20·00	volumes.
Vaporized water	2·84	"
Carbonic acid	4·76	"
	27·60	"

Possessing thus the numbers N of gaseous molecules, we determine in the following manner the values of Σ in the neighborhood of the temperature of combustion sought for:

Heatings at	1,900°	2,000°	2,100°	2,500°	2,600°
Of 20·00 volumes of azote	302·80	321·00	339·60	416·20	436·00
Of 2·84 volumes of steam	73·35	78·83	84·46	108·80	115·40
Of 4·76 volumes of carbonic acid	140·65	151·51	162·69	211·34	224·50
	516·80	$q_1 = 551·34$	$q_2 = 586·75$	736·34	775·90

As, on the other part, $q = 559$, the temperature of combustion sought for is visibly placed between 2,000° and 2,100°. We have, finally, with very close approximation,

$$\theta = 2000 + (559 - 551)\,\frac{100}{587 - 551} = 2020^\circ \text{ C.}$$

The values above of the heatings at 2,500° and at 2,600° enable an idea to be had of the influence that would be exerted on the value of the flame by the previous heating of the air to 1,000° for example. In this hypothesis, the quantity q would be formed not only of the number of calories due to the heat of the combustion, but also of the number of calories carried by 25 volumes of air heated to 1,000°, $q = 559 + 25 \times 7·43$; according to the table of the heatings $q = 559 + 186 = 745$ calories. Completing the calculation we find $\theta = 2,520^\circ$. The previous heating of the air to 1,000° has raised the temperature of combustion about 500° C.

(3) *Temperature of Combustion of a Coal.*—Take, for example, the coal of Treuil (St. Etienne).

The elementary analysis of this coal has given abstraction made of ash and hygroscopic water:*

Carbon	89·23
Hydrogen	5·03
Oxygen and azote	5·74

Supposing the water resulting from the combustion to be vaporized the calorific power is 8,580 calories.

The method of calculation employed for the peat is here applicable without modification. We find, notably in the gaseous residue, the following composition in molecular volumes:

Azote	34·00
Superheated steam	2·50
Carbonic acid	7·40
Total	43·90

corresponding to 42·50 volumes of air used in the combustion.

Value of the flame (cold air)	2,010°
Value of the flame (air at 1,000°)	2,570°

I add that the reader will find other examples, notably in what concerns gaseous combustibles, in Mr. Damour's book already cited.

IV. Results of Calculations.

I have applied the preceding method to the calculation of the value of the flame of a certain number of combustibles. In order to render more easy the comparison of the results, I have supposed these combustibles to be deprived of their ash and hygroscopic water.

I have taken the elementary analyses and the calorific powers from pages 54, 59 and 80 of my work, entitled "Etudes sur les Combustibles." The following table gives the figures obtained.

The value of the flame varies very little from one combustible to another. The mean of sixteen enumerated is 1,986°, and it seems that the round number 2,000° can be adopted as representing the theoretical temperature of combustion of any combustible whatever of vegetable origin. As absolutely rigorous constants could not be obtained for the process I have described, a more precise number is useless.

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* Combustibles, such as coal and peat, always contain a certain quantity of hygroscopic water which passes entirely into the gases of combustion. It is very easy to take account of this water in the calculation of the temperature.

Designation of the Combustibles.	Calorific Power.		Value of the Flame.
	Water Condensed.	Water Vaporized.	
	Calories.	Calories.	Centigrade Degrees.
Oak from Lorraine	4,690	4,370	1,865
Peat from Bohemia	5,900	5,590	2,020
Lignite from Trifail	6,650	6,370	1,960
Flaming coal from Blanzy (Ste. Marie)	8,350	8,060	1,990
Flaming coal from Decazeville (Tramont)	7,840	7,530	1,960
Oxidized coal from Commentry	6,380	6,200	1,960
Gas coal from Commentry	8,410	8,110	1,950
Gas coal from Béthune	8,670	8,380	1,990
Gas coal from Lens	8,740	8,450	2,010
Fat coal from St. Etienne (Treuil)	8,860	8,580	2,010
Marechale coal from Roche-la-Moleire	8,860	8,600	2,030
Semi-fat coal from d'Anzin (St. Marc)	8,660	8,430	1,980
Anthracitic coal from Commentry	8,460	8,290	2,030
Anthracitic coal from Kebao	8,530	8,370	2,020
Anthracitic coal from Creusot	8,690	8,480	2,010
Anthracite coal from Pennsylvania	8,266	8,140	2,000

The value which, in the above table, is the farthest from the mean of 2,000°, is that of oak—1,865°.

The temperatures which are the farthest removed in excess from the mean 2,000° are, in general, those of the anthracitic coal. The popular opinion has always been that anthracite has a hotter flame than coal. The relative value of the flames sustains this opinion.

To the results in the above table can be added those which I have found for different liquid combustibles, as follows:

Ethylic alcohol and methylic alcohol	1,700°
Amylic alcohol	1,850°
Crude American petroleum	2,000° (calorific power, 10,400.)
Essence of American petroleum	1,910° (calorific power, 10,270.)
Refined American petroleum oil	1,660° (calorific power, 10,280.)

Finally, below will be found the temperatures of combustion of several gases under constant pressure.

Hydrogen	1,960°
Oxide of carbon	2,100°
Methane	1,850°
Acetylene	2,350°
Illuminating gas, mean *	1,950°
Water gas, industrial	2,000°

An examination of the numbers grouped in this work shows the apparently paradoxical appearance that of two combustibles, the one having the greatest calorific power is not necessarily the one having the hottest flame.

The flame of the essence of petroleum is relatively cold. The flame of the sample of peat appears hotter than that of the coal of the Treuil, the calorific power of which is excellent. The flame of the oxidized coal from Commentry is a little better than that of the same coal not deteriorated.

Moreover, everything occurs in all cases and, notably, for the combustibles of vegetable origin, as if the elements of the temperature of combustion, calorific power, elementary composition, volume and composition of the gases of combustion, compensated each other so as to give to all the combustibles flames of very nearly the same thermometric degrees of temperature.

This, however, does not lessen the advantages due to the high calorific power of good coals, and which is the true measure of their value, since the flame utilizable of a coal is a great deal more voluminous than that of a peat, a very much oxidized matter, the combustion of which requires but very little air.

We have seen, for example, that the combustion of 100 grams of Bohemian peat corresponds to the disengagement of 28 volumes of gases of combustion at 2,000°, while the gaseous residue of the coal from the Treuil attains 44 units † at the same temperature.

OCTOBER, 1903.

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* According to Mr. A. Sainte-Claire Deville ("Société Technique de l'Industrie du Gaz," 1903.)

† The use of hot air for improving the flame, from the thermometric point of view, is certainly more efficacious in the furnaces in which coal is burned than in those in which an inferior combustible is burned.

ELECTRIC SMELTING OF IRON ORES.

This subject has recently been made the subject of investigation by an expert commission appointed by the Canadian Government, whose study of the subject was directed particularly to the question as it affected the iron-ore deposits of Canada. The commission made a tour of the best-known electric iron-smelting furnaces in Europe, and its findings have been embodied in a report which has recently been issued by the Canadian Department of Mines. Its conclusions are summed up in the statement that pig iron can be produced on a commercial scale, at a price to compete with the blast furnace, only when electric energy is very cheap and fuel very dear. It was found that on the basis assumed in the report, with electric energy at $10 per electric horse-power year, and with coke at $7 per ton, the cost of production is the same as the cost of producing pig iron in a modern blast furnace. Under ordinary conditions, where blast furnaces are an established industry, electric smelting cannot compete; but in special cases, where ample water power is available and blast-furnace coke cannot be readily obtained, electric smelting may be commercially successful. On the other hand, although the cost of electric ore reduction prevents it from competing with either the Bessemer or the Siemens open-hearth process in the production of the common grades of commercial steel, the process was found to be in successful commercial use in the production of high-grade crucible steel.

Now the report of this commission, outside of having fulfilled the immediate purpose for which it was presented, should serve as a safeguard to the general public against being led into hasty and undigested schemes for the smelting of iron ore. The figure of $10 per electric horse-power year can only be realized under very exceptional circumstances, where water is abundant, readily available and contiguous to large deposits of iron ore. We believe that the lowest figures obtainable at Niagara are from $15 to $20 per horse-power, and here, because of the size of the plant, and the unlimited volume and great head of water available, the conditions are ideal for cheap production. It may be that some of the large plants which, during the past few years, have been hurriedly erected on a scale far beyond the immediate local demand for power, are making contracts at prices that give very little, if any, return on the investment; and great care should be exercised in using such low figures as a basis of indiscriminate estimate of the cost of electric iron-ore reduction.—*Scientific American.*

RHINE-DANUBE SHIP CANAL.

A ship canal to connect the Rhine and the Danube, which will have a total length of 181½ miles, has been proposed. The cost is estimated at about $35,000,000, of which $10,000,000 would be absorbed by the canalization of the River Neckar, which is one feature of the scheme. It is thought, however, that an asset value of $6,000,000 or $7,000,000 would accrue from the water power of the various locks. The length from Mannheim on the Rhine to Neckarems on the Neckar is 110 miles, and thence to the Danube is 71½ miles. This canal would place the now more or less isolated kingdom of Wuerttemberg in the middle of the largest and most important waterway of Europe.

CHEMICAL SECTION.

Stated Meeting, held Thursday, November 10, 1904.

Salt-Making in the Far-West.

By E. Goldsmith.

By reason of the cost of transportation across the continent, table salt, on the Pacific Coast, at one time was rather high in price.

It seems, according to information obtained in Salt Lake City, Utah, that the Mormons were the first who found rock salt about seventy miles away from their settlement near the Great Salt Lake.

Although there was plenty of salt in the lake, they preferred, for certain reasons, unknown to the writer, to haul their salt supply from the deposit in the Wasatch Mountain.

It follows, therefore, that the people in Utah and adjacent territories were not dependent on the Eastern States for their supply of table salt. It appears, however, that the earlier settlers on the west coast of North America drew at least a part of their supplies of salt from the Eastern States until they began to see a margin in the winning of the salt from the waters of the Pacific Ocean. The fact is, as the writer learned in a recent visit to the Pacific Coast, that salt-making, as they called it, is a thriving industry there at the present time.

The long dry season of about eight months or longer during the year, favors the winning of salt from the ocean in a high degree.

Cheap and flat land a few feet above the sea level, away from human habitations and not approachable by cattle or the sheep herder, to avoid contamination and other troubles, is best suited for the salt industry.

Of course, it requires some preparation of the land. Let us imagine a five or ten acre lot of ground to be prepared to form an evaporating pan.

It seems that, after some leveling with pick and shovel, wooden boards are driven into the sand to form the sides of the pan. Now, they cover the boards all around with the sand from within, forming on both sides a slope. The height is about 10 to 12 inches. I was told that some parties used no boards at all, that the triangular elevation or rim of sand would hold without an internal board. These tapering sides of the large level sand pan are strong enough, so long as no storm is raging, because there is not much pressure against them.

We have now an earth- or sand-evaporating pan for salt-making from ocean-water, or from the water of the Great Salt Lake of Utah.

To do the work on a large scale it is only necessary to multiply the number of such earth or sand pans, so as to have, say, a thousand acres or more of surface to be filled with the brine and let the solar heat do the work of evaporating the water, when in due time the salt, after sufficient concentration, will crystallize in cubes and collect at the bottom of the pan.

They usually fill these huge earth pans to about 6 inches, more or less, with the salty water by using comparatively small steam pumps. A small wooden shanty is seen at various locations in the salt plant, usually at a corner, in such a position that a number of pans may be filled and refilled with the same steam pump.

I have not noticed any provision of a general reservoir from which all the earth pans receive their filling with the brine through a system of pipes. It appears, therefore, that the salt-water is raised for each sand pan separately; but there exist also connections between the pans whenever they are on the same level. After a certain number of days, when the water has in part disappeared, the filling is repeated, and so on until a good heavy crop of crude salt covers the bottom of the pan.

The crude salt is now ready to be collected. It is the custom to pile it into quadrangular masses, usually on one of the longer sides of the earth pan. In the scraping of the salt into a pile the workman must avoid the sand, and, therefore, scrapes gently over the layer in such a manner as to leave a thin crust of salt on the sandy bottom of the pan. The piles of crude salt, many tons in weight, are now allowed to drain for some time, and the mass is then ready to be transported to the refining house. For this purpose the crude material is loaded on freight cars conveniently at hand. Without such transportation facilities, it will be manifest that the cost of labor for hauling to the refining plant might absorb the profits and cause the failure of the enterprise.

Now, in Europe the refining of sea or lake salt is generally effected by a system of fractional crystallization, washing and drying the product ; that is to say, from the original brine direct, and not by a re-solution of the crude salt and re-crystallization as is the general practice and requirements in other similar chemical processes.

The French salt producer on the Atlantic Coast watches with care the concentration of the brine and observes the formation of the pellicles of salt forming and floating on the surface of the mother liquor. These small crystals of salt are considered the purest and, therefore, of the best quality that can be obtained under those conditions. It constitutes the table salt of the people of France and is considered to be a satisfactory market product. But it must not be supposed to be chemically pure ; it is rarely better than 97 per cent. ; and if occasionally it is found to be a little better, it is exceptional.

Generally speaking, the percentage of the pure salt is below 97 per cent., and sometimes it is found in the market as low as 90 per cent. The second and third crops of salt are utilized for industrial purposes.

In Utah and California an entirely different method of refining the crude salt has been developed.

The method adopted there—in the Far West—may be termed " the dry refining of salt."

As has been indicated above, no notice is taken of a first, second, or third crop of crystal salt in the sandy earth-pans by our Western salt producers. On the contrary, they allow the crop of salt to grow as much as possible ;

rake it together, let it drain, and refine it by their own dry method.

This dry method of refining table salt is based on the following conditions:

(1) We have a mixture of anhydrous sodium chloride and two hydrated magnesium salts, to wit: magnesium sulphate and magnesium chloride; sometimes also calcium chloride and sulphate of sodium is present.

(2) If these two magnesium salts are removed, it is self-evident that the residue will be pure table salt (NaCl).

(3) If this mixture of salts be heated and all the water of crystallization contained therein be driven off, the magnesium salts are converted to a fine, pulverulent condition which may be removed by a current of air. Experiments have fully proven the correctness of this method. I am sorry to say that the name of the inventor of the process has not been disclosed. However, from data obtained in California and in Salt Lake City, Utah, I am satisfied that the Mormons exploited the first plant for refining table salt on a large scale by the dry process.

The refining process carried on at the work near Salt-Air, Utah, is a continuous one. A slowly rotating cylinder, apparently made of wood, about 30 feet long and roughly estimated about 6 feet in diameter, is caused to make about one revolution in four or five minutes. In the inner part of this cylinder is fixed an iron cylinder about 12 or 16 inches in diameter, which is charged, as I am informed, with superheated steam, supplied and connected by the necessary coil and steam generator. This is the dryer.

The salt, in the wet state, is fed into the hottest end of the dryer by a screw carrier, made of iron. Within this long cylindrical dryer it is slowly moved forward towards the other end by means of an arrangement that keeps the layer of salt evenly and thinly spread over the whole length of the dryer. The water is thus vaporized and carried off through a flue urged with the aid of an exhaust fan driven at considerable speed. The exhaust fan which carries off the vapor of water at the same time carries with it the now fine dust of the two magnesium salts; thus doing double service.

At the further end of the cylinder the dry hot salt falls upon a sieve, where another separation takes place, namely: all of the material that has formed into lumps is caught upon the sieve. On taking a sample of the sifted salt from the receiving box the salt felt quite hot. Looking critically upon the small crystals I saw that there was still some little of the white dry powder adhering to them, indicating that the magnesia salts had not been entirely removed. I made the remark to the guide (one of the workmen) who showed me through the works, that the separation was not complete; and he acknowledged the fact that by one blowing—as he termed it—the separation of the impurities could not be completely effected, but that a second and third grinding and sifting and blowing was required to finish the salt for table use.

The successive transportations of the material were effected as in a flour-mill, by horizontal and vertical belts on which triangular boxes were fixed to receive and carry the salt to another point. To avoid any contamination, through dust or dirt, the entire system of belt carriers was run in quadrangular wooden boxes well fitted together.

The best grade of salt, for table use, is ground very fine; and it is not possible to recognize the presence of any of the magnesium salts without a chemical analysis. I did not take along a sample for chemical examination, and hence withhold judgment with regard to the perfect separation of the magnesium salts from the sodium chloride for table use produced at the Works of Salt Air. So far as appearances go the article was good and had no bitter taste. Whether the salt will keep dry in a moist atmosphere is a question I am unable to answer. I saw some samples of salt from the Pacific Coast at the St. Louis Exposition which showed signs of moisture to some extent. While there I tried to find samples of salt from Salt Air, Utah, but without success. My object was, of course, to observe what effect, if any, the moist atmosphere of St. Louis would have upon the product.

I could hardly believe it possible that all the magnesium salts could be removed from chloride sodium by the dry process; but it seems that the article is at least as good as the French, and that suffices. At any rate, the material is produced in the West on a very large scale, considering the population.

The output is from 150,000 to 200,000 tons annually, which is far in excess of what is needed for home consumption. It is even exported to the Hawaiian Islands and other points. It is accepted by the consumer as satisfactory, and that proves better than any other criticism that the dry process of refining table salt is an accomplished fact.

The current of forced air which drives the dry, dusty magnesium salts away from the sodium chloride along with the vapor of water carries with it some of the sodium chloride. This is shown by the fact that on top of the building, near the flues, there is a fairly thick, white deposit of the mixed salts, which would run down the roof if much moisture were in the air.

In the Salt Air Works this separated mixture of salts is not thrown away, but is made available by mixing it with about one-fifth its weight of sulphur and heating the mass to form blocks. These keep fairly dry and are sold to the dairymen and cattle raisers as lick-salt. It finds a market, and my informant told me that the demand for it was greater than the supply.

SUBMERGED COAL EXPERIMENTS.

Some time ago we drew attention to the experiments that were being carried out by the British Admiralty with submerged coal. In May, 1903, five crates of coal, each holding two tons, were sunk in a basin at Portsmouth, and a similar quantity was placed at the coaling point on land, in small heaps, covered with tarpaulins. Six months ago some of the submerged coal was raised and burnt, in conjunction with a similar quantity of that which had been kept on land, and the results showed that the submerged coal had greater calorific qualities. Owing to the success of this test, further experiments are to be carried out on the same basis.—*Scientific American.*

STEEL RAILWAY TIES.

Officials of the Lake Shore Railroad have placed an order for 7,000 steel ties to be used as an experiment, probably near the eastern terminus of the road at Buffalo. Part of the order will be used on the New York Central, and if the results are satisfactory it is expected that a more general use of steel ties will be made by the Vanderbilt roads.

Mechanical and Engineering Section.

(*Stated Meeting held November 25, 1904.*)

The United States Patent Laws: Historically and Practically Considered.*

By Cyrus N. Anderson,
of the Philadelphia Bar.

Several years ago a writer in the *Iron Industry Gazette*, an English publication, said: "Disparagement of patents is common and easy, but it should not be forgotten by those who sneer at inventions that, out of a total of eight billions of capital invested in manufacturing in the United States, patents form the basis for an investment of about six billions. Evidently, the United States system of encouraging invention that has resulted in the patenting of over 500,000 inventions is a system which is exceedingly wise and valuable. The only thing that has enabled manufacturers to make so wonderful a progress in the United States is its patent system."

Up to the present time, there have been granted in the United States nearly 800,000 patents, and, while I have no recent figures, there is no doubt but that the proportion of capital invested in manufactures with patents as a basis is as great, if not greater, now than it was when the foregoing statement was made.

At a time when the right of property in patents, or rather in patented inventions, is so well recognized, it strikes one as a curious fact that there ever was or should have been a time when a right to such property was not recognized. Yet the fact is that in comparatively recent periods, considered in the light of the world's history, property rights in connection with inventions were not recognized, and if a man was possessed of an inventive turn of mind and was an inventive genius, and made inventions or improvements in machines or in mechanical devices or in the art of doing things, he had to stand by and see others enjoy equally with him the benefits of his intellectual thought and effort.

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* Read at the stated meeting of the Business and Professional Club for November, 1904, and (by title) before the Mechanical and Engineering Section of the Institute, November 25, 1904.

In the very earliest history, the right of property in tangible things was recognized, but an exclusive right in intellectual property, such as inventions and writings, was not regarded as a natural right, and the right to such property was only established as a result of advancing and improved civilization.

It seems that quite early in England the practice grew up under which the Crown, as a matter of grace and favor, but not of right, granted to the inventor of a new manufacture or a new art, the exclusive right for limited periods to his invention or improvement, and it is reported that in the fourteenth century, in the reign of Edward III, some wise subjects of the realm, alchemists they were, invented or discovered a philosopher's stone. A commission was appointed by the King, consisting of two aldermen and two friars, who, after an investigation, which, of course, was very carefully made, reported that the philosopher's stone possessed merit, and upon this report the King granted an exclusive right to the discoverers to manufacture and sell the philosopher's stone.

When the nature of intellectual property is considered, it seems somewhat anomalous that rights of property therein should not have been recognized from the very earliest times.

Professor Shaler has said: "When we come to weigh the rights of the several sorts of property which can be held by men, and in this judgment take only the absolute questions of justice, leaving out the limitations of expedience and prejudice, it will be seen clearly that intellectual property is after all, the only possession in the world. The man who brings out of nothingness some child of his thoughts has rights therein which cannot belong to any source of property."

Mr. Fessenden, in his work on patents, published in 1821, says: "In a moral as well as in a political point of view, the author of a new and useful invention has the best of all possible titles to a monopoly of the first fruits of his ingenuity. The invention is the work of his hands and the offspring of his intellect; and after he is allowed a temporary monopoly, becomes at the expiration of the patent a valuable donation to society."

At least as early as about the year 1600 the right of property in invention was well understood and had a well-established and defined standing in the common law. As indicating that in the common law of England at that time the reason for granting exclusive privileges to inventors, and that the rights of property in inventions were fairly understood, I will read you what was said by the Court in the case of Darcy *vs.* Allin: "Where any man, by his own charge and industry, or by his own wit or invention, doth bring any new trade into the realm, or any engine tending to the furtherance of a trade that was never used before; and that for the good of the realm: that in such cases the King may grant to him a monopoly patent for some reasonable time, until the subjects may learn the same, in consideration of the good that he doth bring by his invention to the commonwealth; otherwise not."

Sir Edward Coke said of patent privileges that: "The reason wherefor such a privilege is good in law is because the inventor bringeth to and for the commonwealth a new manufacture by his invention, costs and charges, and therefore it is reason that he should have a privilege for his reward (and the encouragement of others in the like) for a convenient time."

It does not appear that there was any statutory law passed in England concerning the patenting of inventions until the year 1623, in the twenty-first year of the reign of James I, at which time the statute of monopolies was passed, which declared certain monopolies to be void, and prohibited the grant of such monopolies in the future. One section of this statute, however, related to patents and read as follows:

"Provided also, and be it declared and enacted: That any declaration before mentioned shall not extend to any letters-patent and grants of privilege, for the term of fourteen years or under, hereafter to be made, of the sole working or making of any manner of new manufactures, within this realm, to the true and first inventor and inventors of such manufactures, which others, at the time of making such letters-patent and grant, shall not use, so as also they be not contrary to the law, nor mischievous to the state, by raising prices of commodities at home, or hurt of trade, or generally inconvenient: The said fourteen years to be accounted from the date of the first letters-patent or grant of such privilege, hereafter to be made; but that the same shall be of such force as they should be, if this act had never been made and of none other."

I quote this section of the statute in full because it is the first English statute on the subject, and is the very foundation of our own laws on the subject of patents. These laws are the result of development and evolution.

Mr. Robinson, the author of one of our most elaborate treatises on the subject of the patent laws, has said that in this statute, as interpreted by the English courts, are found the sources of the patent laws of the United States.

The 150 years following the statute just referred to covered the Colonial period of the United States. During that period of our existence there was, as is well known to all, very little manufacturing within the present borders of the United States, and very little improvement in the manufacturing arts was made by the Colonists. The country was very thinly and sparsely settled; the Colonists, our forefathers, had duties to perform which were much more pressing upon them than the making of inventions or improvements in the method or art of doing things in the manufacturing world. The Colonists were making a continual fight for existence and constant effort to subdue the many obstacles incident to the development of a new country, and had no time to engage in the fascinating and frequently profitable pursuit of making improvements and inventions in existing devices in the manufacturing arts.

It is not surprising that under these conditions the Colonists made few inventions. But there was still another obstacle in the way of improvement by the Colonists of the manufacturing arts. This obstacle was the attitude of England toward the Colonists upon this matter. It was England's idea that the Colonists should supply raw articles of commerce, such as the products of the farm, and that England should furnish to the Colonists all such manufactured articles as might be needed or demanded by the Colonists. England's policy toward the Colonists was expressed by Sir William Pitt, when he said: "It is the destiny of America to feed Great Britain, and the destiny of Great Britain to clothe America." Lord Chatham said, "I would not allow the Colonists to make so much as a hob nail for themselves."

Laws were enacted by England prohibiting every species of manufactures in the Colonies. When the Colonists began to make iron and nails for their use, the House of Commons resolved that "none of the plantations should manufacture iron nails of any kind out of any sows, pigs, whatsoever." And the House of Lords added, "No forge going by water, or other works, should be erected in any of the plantations for the making, working or converting of any sows, pigs, or cast iron into bar or rod iron."

By an act of 1750 the erection of buildings and mills for making iron was prohibited. There were corresponding restrictions imposed upon the Colonies with respect to all sorts of manufacturing arts. For instance, in 1684, Virginia passed an act encouraging the manufacture of the textile fabrics which was annulled by Parliament. The condition of manufactures in the Colonies has been well set forth by Senator Thomas C. Platt, of Connecticut, as follows:

"Manufactures were practically unknown; . . . there were no machines as we now understand the term; . . . men knew how to plough and sow, hoe and chop, reap, mow and cradle, break flax and hackle it, thresh with the flail, winnow with the blanket or fan and to shell corn by hand. The women knew how to spin, card, weave and knit. Mechanical knowledge was monopolized by the blacksmith, the carpenter, the millwright and the village tinker. Production was a toilsome, weary task, limited by the capacity for muscular endurance."

It is probable that the first patent granted within the limits of the United States was by the general court of the Colony of Massachusetts, under date of May 6, 1646, to one Joseph Jenckes, of Lynn, for a scythe. In his petition or prayer, he prayed for protection for "Fowerteen yeeres, without disturbance by any other setting up the like inventions, so that his study and cost may not be in vayne or lost."

Before proceeding to a discussion of the laws relating to patents which have been enacted by the United States Government, I desire to call attention briefly to some of the objections which have been made to patents. The objection has been made that there is no such thing as intellectual property, and that ownership of such property restricts common rights. Also that the granting of a patent is a creation of a monopoly. Patents have been compared to letters of marque, which allowed the holder to prey upon honest industry. It has been urged that patents increase the price of commodities, and that they encourage labor-saving inventions and take opportunities from the artisan.

It is needless to say to an audience of the present day that the last objection is utterly without foundation. Exactly the reverse has been proved adequately. It has been urged that patented inventions reduce or sink man to automata, and that the granting of a patent enables one man to say to another that he shall not carry on his business in the best way, and that by granting a patent the idea involved in the patent is tied up, and the course of thought in that direction is stayed. A Frenchman has advanced a picturesque objection that patents give undue advantage to their possessor by "making a golden bridge for him who enters the arena with arms more subtle and more finely tempered than those of his adversaries."

The foundation of all the patent-law legislation in the United States is the clause or phrase in the Constitution which vests in Congress power "to promote the progress of science and useful arts by securing for limited times to authors and inventors the exclusive right to their respective writings or discoveries."

The first patent law of the United States was enacted in the year 1790, April the 10th. It followed in a general way the law then in existence in England authorizing the grant of patents without an examination of the prior art, as is now the case. The authority to grant patents was conferred upon the Secretary of State, the Secretary of War and the Attorney-General of the United States.

It appears that Mr. Jefferson, who was at that time Secretary of State, took great interest in the patent laws, and regarded them and the granting of a patent as of the very greatest importance, and he is generally referred to as the Father of the United States Patent Laws.

In the Official Gazette of the United States Patent Office, published September 24, 1877, an interesting description of the early practice under the Act of 1790 occurs: "By Act of April 10, 1790, the first American Patent System was founded. Thomas Jefferson inspired it, and may be said to have been the Father of the American Patent Office. He took great pride in it, it is said, and gave personal consideration to every application that was made for a patent during the years between 1790 and 1793, while the power of revision and rejection granted by that Act remained in force. It is related that the granting of a patent was held to be in these early times quite an event in the history of the State Department, where the clerical part of the work was then performed.

It is a matter of tradition, handed down to us from generation to generation, by those who love to speak of Mr. Jefferson, his virtues and his eccentricities, that when an application for patent was made under the first Act, he would summon Mr. Henry Knox, of Massachusetts, who was Secretary of War, and Mr. Edmund Randolph, of Virginia, who was Attorney General—these officers being designated by the Act, with the Secretary of State, a tribunal to examine and grant patents—and that these three distinguished officials would examine the applications critically, scrutinize each point of the specification and claims carefully and rigorously. The result of this examination was that during the first year, a majority of the applications filed failed to pass the ordeal, and only three patents were granted. In those days every step in the issuance of a patent was taken with great caution, Mr. Jefferson seeking always to impress upon the minds of his officers and the public that the granting of a patent was a matter of no ordinary importance."

It is not to be understood that the examination referred to an investigation of the prior art. The only examination required was of the petition, description, drawing, etc., of the application.

The next patent act was amendatory in its nature, and was passed in 1793. Among other changes, it imposed the duty of issuing patents upon the Secretary of State, subject, however, to the approval of the Attorney General.

From 1793 down to 1836, various unimportant amendments to the patent laws were enacted. In the last mentioned year, however, the first comprehensive law was passed relating to the grant of patents. This law remained in force until 1870, and was in fact in substance very much the same as our present laws.

By the enactment of 1836, a sub-department of the State Department was created, which was known as the Patent Office. Provision was made for the appointment of a Commissioner of Patents, and the Commissioner of Patents was required to make or to have made an examination of the alleged new invention or discovery to determine whether or not the same had been invented or discovered by any other person in the United States prior to the alleged invention thereof by the applicant and to determine whether or not, in view of the prior art, the applicant was entitled to a patent.

Prior to this Act examinations were not required, and if the applicant averred that his alleged invention was new and novel, the Commission or the Secretary of State was required to grant or issue a patent upon his application, provided the discovery or invention of the applicant was deemed of sufficient importance.

It will readily be seen that a patent granted under such circumstances was necessarily of very small commercial value, because it would not be reasonable to expect men to invest their capital in a species of property good title to which and the value of which were so uncertain.

The Act of 1836 established patent property upon a higher plane than it had ever before occupied and it is believed that the importance of this act to the people of the United States cannot be overestimated.

Senator Thomas C. Platt, speaking in 1884, referring to this Act, said:

"To my mind, the passage of the Act of 1836 creating the Patent Office marks the most important epoch in the history of our development—I think, the most important event in the history of our Government from the Constitution until the Civil War. The establishment of the Patent Office marked the commencement of that marvelous development of the resources of the country which is the admiration and wonder of the world, a development which challenges all history for a parallel; and it is not too much to say that this unexampled progress has been not only dependent upon, but has been coincident with, the growth and development of the patent system of this country. Words fail in attempting to portray the advancement of this country for the last fifty years. We have had fifty years of progress, fifty years of inventions applied to the everyday wants of life, fifty years of patent encouragement, and fifty years of a development in wealth, resources, grandeur, culture, power which is little short of miraculous. Population, production, business, wealth, comfort, culture, power, grandeur, these have all kept step with the expansion of the inventive genius of the country; and this progess has been made possible only by the inventions of its citizens. All history confirms us in the conclusion that it is the development by the mechanic arts of the industries of a country which brings to it greatness and power and glory. No purely agricultural, pastoral people ever achieved any high standing among the nations of the earth. It is only when the brain evolves and the cunning hand fashions labor-saving machines that a nation begins to throb with new energy and life and expands with a new growth. It is only when thought wrings from nature her untold secret treasures that solid wealth and strength are accumulated by a people."

Under the patent laws now in force in the United States any person who has invented or discovered any new and useful art, machine, manufacture or composition of matter, or any new and useful improvement thereof, not known or used by others in this country before his invention or discovery thereof, and not patented or described in any printed publication in this or any foreign country, before his invention or discovery thereof, or more than two years prior to his application, and not in public use or on sale in this country more than two years prior to his application, unless the same is proved to have been abandoned, may, upon payment of the fees required by law and other due proceedings had, obtain a patent therefor.

It may be remarked here that the word "discovered" in this section of the statute means "invention."

It will be noted that foreigners have the same rights under this law as citizens of the United States.

The first requisite to the securing of a patent is the making of an invention. Just what invention is or what it takes to constitute an act of invention is a question that has been discussed by the courts and by text-book writers many, many times, and it is a question which cannot be answered by definition. I say this, notwithstanding that definitions of the term "invention" will be found in many text-books, and in many decisions of the courts. Suffice it to say that invention comprehends a new idea of means and it must be something beyond the scope of merely mechanical effort.

Having made an invention, the next step in the process of securing a patent consists in the preparation of an application and the filing of the same in the Patent Office. This application comprises a petition to the Commissioner of Patents, requesting the grant of the patent for the invention disclosed in the application, an oath answering to the requirements of the statutes, a specification descriptive of the invention, and such specification must be concluded with a claim or claims specifically pointing out the improvement or invention. If no application has been made in a foreign country, the oath should set forth that the applicant is the original and first inventor of the invention disclosed in the application and described and claimed in the specification; that such invention was never known or used before his invention or discovery thereof; that such invention had not been patented or described in any printed publication in the United States of America or any foreign country before his invention or discovery thereof, or more than two years prior to his application; that the said invention had not been in public use or on sale in the United States for more than two years prior to his application, and that no application for foreign patent had been filed by him or his legal representatives or assigns in any foreign country prior to his application in the United States. If, however, applications for patents in countries foreign to the United States have been made at the time of the filing of an application in the United States, it is necessary for the applicant to name the foreign country or countries in which such applications have been made, giving the date of the filing of the same.

The claims are necessary to a complete specification. The specification must, of course, be signed by the applicant, who in nearly all cases is the inventor, and the application when forwarded to the Patent Office must be accompanied by the first Government fee of $15. Where the application relates to an invention which can be graphically depicted, it is necessary to prepare and file drawings with and as a part of the application.

If any one of the parts above referred to are omitted, the application will not be accepted by the Patent Office, and the same will not be filed until all of the parts have been received by the Patent Office.

After an application has been received by the Patent Office, it goes to the Application Division, where it is classified, and is then fowarded to the division in the Patent Office in which is to be found the class of machine or art to which the invention belongs. Applications received in the office are examined in regular order, according to their filing dates.

Before the claims of an application are allowed, careful examination of the prior art is made, and only such claims are allowed as distinguish from the constructions disclosed by the patents and other publications discovered by the examiner in his search of the art.

As a rule these examinations are carefully made, though, as you will readily understand, where several hundred examiners and assistants are employed, some of them are more careful in their work than others. The more care taken in the search and examination of the records in the Patent Office, the more likely is it that the patented claims will be valid.

It frequently becomes necessary to amend the claims, perhaps many times, before they can be brought into such shape that they distinguish from the art.

There is one thing that should be understood by all applicants for patents, and that is that the claims of a patent are of the very greatest importance; in fact, I should regard the claims as the most important part of a patent. Unless the claims are well drawn and unless they cover well the invention forming the subject-matter of the patent, the patent loses much of its value.

The phraseology of the claims should be accurate. It is as necessary that the elements or parts entering into and forming the combination set forth in a claim should be stated and put together with exactness and precision as it is that the same elements be fitted together with exactness and precision in the machine itself.

As I have already said, the claims of a patent should be drawn with very great care, and should be made as accurate and as exact and as much to the point as it is possible.

I am sorry to say, however, that in many, many instances claims are vaguely and loosely drawn. This in some instances is due to a lack of knowledge of what the invention really is; in others it is a lack of ability to express ideas clearly in writing; in others it is perhaps a lack of effort;

and in others it is perhaps due to a lack of proper time; but whatever the cause may be, failure to secure good claims is a misfortune so far as the patentee is concerned.

A writer in *The Forum*, referring to the difficulty of claim writing, has said: "It takes a very experienced hand to avoid defects which will nullify the patentee's proper advantage. An omission is fatal; an addition is fatal; and a vagueness is fatal."

Broadly considered, the claims of an application may be divided into generic and specific claims. If the invention disclosed in an application will support a broad or generic claim, such a claim should by all means be included. But in addition to such claim, specific claims also should be included because it is very much easier to anticipate a broad claim in the prior art than it is to anticipate a specific claim, and it may happen, if the claims of the patent are ever subjected to litigation, that the patentee would be able to sustain the validity of the specific claim but would be unable to sustain the validity of the generic claim. In such case, the patent, by reason of the presence of the specific claim, would still be of value to the patentee, while, on the contrary, if it had included only the generic or broad claim or claims, which had been anticipated, the value of the patent would be entirely destroyed.

It is not always so, but, generally speaking, a broad claim includes a small number of elements in combination, while a specific claim will include a greater number of elements in combination, and these elements may be still further affected and narrowed by qualifying limitations.

It sometimes happens that an inventor, who fully understands the details and principles of his invention, concludes that he is better fitted to write his specification and claims, that is to say, is better fitted to prepare his application for the Patent Office than some one who has had experience in the writing of specifications and the drawing of claims, and therefore undertakes to do this work. It is very unusual to find an inventor who has had sufficient experience to prepare the specification and claims of an application properly, and the chances are about one hundred to one against his succeeding in drawing claims which adequately protect his invention.

After the application has been placed in condition for allowance, it is allowed by the examiner, after which it goes to the Issue Division of the Patent Office. Then, upon the payment of the final fee of $20, the patent is printed, the grant is prepared and is signed by the Commissioner of Patents, and the patent is issued under the seal of the Patent Office.

Many inventors suppose that when they have secured their patents their troubles are over, but the fact is that if the invention is of any considerable value or worth, the patentee will be beset by a horde of infringers who will attempt to use the invention and secure the benefit of the inventor's thought and ingenuity.

The patentee can protect his rights only by bringing and prosecuting a suit in the Federal Courts and securing an injunction against infringers.

It seems strange that a person who would not think of trespassing upon the real property of another person, or who would not think of interfering with ordinary chattel property belonging to a stranger, will not hesitate to trespass upon the patented property of another, whenever it appears to him that such trespassing would inure to his advantage, considered from a business and financial standpoint.

Notwithstanding the fact that patented property is constantly being subjected to the attacks of infringers, such property is very valuable, and, as has already been pointed out, constitutes the basis of investment of many millions of dollars in the United States, and it has been asserted in a comparatively recent annual report of one of the Commissioners of Patents " that we mainly owe to our patent system such foothold as we have gained during the past fifty years in foreign lands for our manufactured products."

AN 8-FOOT STEEL CHIMNEY, 230 feet in height, has just been completed and will be erected in Mexico. This will be the highest steel chimney in America.

Mechanical and Engineering Section.

Stated Meeting, held Thursday, December 1, 1904.

Physical Characteristics of Certain Bronzes for Steam Uses.

BY STRICKLAND L. KNEASS,
Member of the Institute.

It is not necessary for the purpose of the present paper to touch upon the history of the bronze alloys, the use of which reaches far back to the dawn of civilization. A vast amount of research has already been given to the subject, and the early methods employed in their production have been entirely superseded, so that even an accurate description would have but little practical value to the modern metallurgist or manufacturer.

The copper-tin alloys in general use vary from 5 to 24 parts by weight of copper to 1 of tin, with a small percentage of either zinc or lead or of both elements. The true binary has a comparatively small part to play in the arts and trades compared with the total amount of bronze in use, because the cost and difficulty of tooling and machining is much greater, and lead, zinc, nickel, phosphorus or aluminum are almost always introduced, producing a beneficial effect upon the physical characteristics. For example, a trace of zinc is used in a 5 to 1 mixture for certain kinds of spindle-bearings or sleeve nuts, producing a metal hard and brittle, having a whitish-gray fracture, machining with a short chip which flies from the tool with great force; care is required to obtain a good smooth surface, but when obtained the bearing wears well under heavy pressures. A ratio of 7 of copper to 1 of tin, and a little more zinc, makes a good hydraulic bronze, with sufficiently high tensile strength for all ordinary purposes, machining well and running solid in the mold, even with large size sections.

Commencing with pure tin and passing through the various proportions of copper until the latter metal is reached, the appearance of the fracture changes from white, through gray, ash-gray, bluish-red, reddish-yellow to the tile-red of pure copper. The melting point changes at the same time with each increment of copper, until that of the latter metal is reached. According to Mallet, the maximum density of the alloy is somewhat above that of copper, and occurs when the proportions by weight are about 3 of copper to 1 of tin.

The chemical union of copper and tin in more than one or two proportions is disputed by many authorities, although the statement has been made before this Institute, that 1 to 1, 1 to 2, 1 to 3 and 1 to 4 are probably alloys.* Be this as it may, in the actual behavior of the binary alloy in the foundry, owing to imperfect mixing or to other reasons, there is almost always found a certain amount of liquation and a proportion of eutectic alloy which affect the physical characteristics.

This subsidiary alloy is much more in evidence, and its presence and amount of greater importance in the quaternary alloys or mixtures of copper, tin, lead and zinc, with which we have to deal in this discussion. Here there is always liquation, depending upon the form and size of the section and the rapidity of cooling. For this reason, great care is required to obtain a perfectly homogeneous mixture, approaching as nearly as possible a chemical alloy, free from microscopic pin holes due to shrinkage or to occluded gases, and without the harder spots or lumps of eutectic alloy of the constituent metals. This is where the skill and care of the foundryman, designer and molder, as well as the composition of the metal, play an important part. The rapidity of melting, temperature of pouring and the condition of the mold itself, all affecting the results.

The essential characteristics of a good steam metal are, homogeneity, solidity, tensile strength, rigidity, facility for machining, fluidity in casting, and non-corrosiveness, all being supplied by the various mixtures of bronze in use in varying degrees of excellence. With reference to the composition it may be said in general that homogeneity depends upon the causes already cited; tensile strength and rigidity upon the proportion of copper to tin and their preponderance over the lead and zinc, while the form and character of the chip is determined chiefly by the percentage of lead and fluidity by the zinc. The proper mixture for any desired purpose must, therefore, be a compromise, with a fixed tendency toward homogeneity and density, and it is not an easy matter to obtain the desired results in foundry work without careful attention to detail and consistent experiment.

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* See this *Journal*, **199**, 26. *Art.* Outerbridge, Microstructure of Bronzes.

And experimental work should not be limited to the examination of etched sections, nor should conclusions be drawn from one set of castings. Specific gravity tests and microscopic examinations are also necessary to cover the field satisfactorily, and are of as much importance in the examination of the physical properties of bronze steam metals, as of iron or steel, and such tests should be repeated at periodic intervals to determine the regularity of product of the foundry.

Bronze castings, both finished and unfinished, are subjected in service to two serious deteriotating agencies, namely, the attrition and the solvent action of the contained fluids. These effects are scarcely noticeable on the rough casting, surfaced as received from the mold or after subjection to the sand blast or cleaning bath, but finished surfaces are often seriously affected. The same result that is obtained in the laboratory by etching polished sections, occurs in practice on an exposed valve or seat, except that the final result is not so satisfactory; the more soluble metals or alloys are dissolved by the acidulous or alkaline solution, leaving the more resisting and harder eutectic alloy to protrude above the surfaces, preventing continuous contact between the valve faces. Further, the high velocity of the fluid passing through a throttled valve, cuts out the softer parts and a bad leak and defective seat soon result.

The porosity of the casting deserves serious consideration, even though the openings be not visible to the naked eye. These defects are seldom observed with a high-power microscope, with the vertical illumination usually employed. The degree of porosity generally depends upon the size of the casting and the part of the section chosen for examination, and is a function of the rapidity with which the molten metal is cooled.

Referring to the effect of attrition in special cases, it may be said that when an injector for feeding boilers is operated at its minimum capacity, the velocity of the jet of water and partly condensed steam may reach 800 feet per second, with a side pressure against the walls of the tube of from 80 to 100 pounds per square inch. If to the passing fluid be added a percentage of sand or dirt often contained in the water supply, the abrasive effect is rapid. A steam line carrying 200 pounds pressure gives a maximum velocity of discharge through a throttled valve of 1,400 feet per second. Hydraulic valves made of bronze are frequently subjected to a pressure of 4,000 pounds per square inch, and the velocity of the water or oil through the constricted orifice between the supply and exhaust may reach 2,400 feet per second during the opening or closing of the valve. The abrasive effect in the cases cited is therefore obvious, and any defect in the surface of the metals exposed to such action is sure to cause rapid deterioration in the operation and efficiency of the device. In injectors made of defective material, the tubes wear out rapidly, not only losing their correct proportions, but, owing to the peculiar action of the jet of steam in apparatus of this kind, grooves and depressions are cut in the inner walls, which cause a ricochetting action from one side of the tube to the other, and which finally prevents the jet from passing into the boiler. The harder protruding spots of the eutectic remain unaffected, while the softer parts directly behind them and exposed to the abrasive action of the fluids, are cut below the normal surface. In the steam-nozzle of an injector, this effect is more marked when a large percentage of water is carried, while dry steam does but little harm to a well-designed nozzle, made of good bronze of even density.

As strength and rigidity are largely questions of the proportions of parts in the design, it is my intention to lay special stress upon homogeneity and density.

Without giving the full details of the investigations, it may be of interest to suggest an outline of the experiments to determine the effect of foundry practice upon the density and homogeneity of certain bronzes. A number of tests were made of various mixtures of copper, tin, lead and zinc having a specific gravity of from 8·5 to 8·9, and an ultimate tensile strength from 25,000 to 30,000 pounds per square inch. The test pieces were turned to ⅝ inch diameter and 6 inches long, while the specimens for microscopic examination were flat discs about ⅛ inch thick and 1½ inch diameter and short cylinders about ¾ inch x ⅝ inch. The test pieces were strained to breakage, and the specimen sections etched and examined microscopically for distribution of liquation, or surfaced for determination of porosity, while the densities of both sets were obtained. It was found that great care was necessary in preparing specimens for examination under the microscope for porosity; a sharp tool and a fine feed must be used to avoid the burnishing effect of a facing tool, as the latter closes up the pores to a great extent; it is also necessary to use a high-cutting speed to prevent the tearing of the metal.

One of the most obvious causes of variation of the quality of steam bronzes is careless mixing of the fluid metal before pouring, yet it is seldom that this is thoroughly done. The great difference in the specific gravities causes the lead to preponderate at the bottom. An extreme case of this kind was proved by specimens, taken from similar castings, poured from the top and bottom of a bail-pot without special stirring; only a trace of lead was found in the first specimen, and the chips curled like steel turnings; the casting from the bottom of the pot contained three times the required amount of lead, was of a dull color and unfit for use.

A careful determination was afterward made of results that might be expected under best conditions; four small cylindrical test-pieces of dimensions already given were taken from the first and last mold poured:

FIRST MOLD.

Specimen No. 1, specific gravity	8·539
“ “ 2, “ “	8·529
“ “ 3, “ “	8·555
“ “ 4, “ “	8·530
Average specific gravity	8·553

LAST MOLD.

Specimen No. 1, specific gravity	8·309
“ “ 2, “ “	8·368
“ “ 3, “ “	8·320
“ “ 4, “ “	8·339
Average specific gravity	8·340

The individual tests are given to show their consistency and the regularity of the composition of the metal; the difference in specific gravity of the two groups is 2·8 per cent., and the castings made first are slightly denser. Four flat discs from the first mold had an average specific gravity of 8·267 and from the last mold 8·010, a variation of 3 per cent. in the same direction. Two more tests of this kind were made, the differences in the specific gravity of each corresponding closely to the table above, the increase in density in the castings from the first part of the heat being respectively 2·9 and 3·4 per cent. The conclusion to be drawn is that there is no difficulty in obtaining castings of uniform density if the metal is properly mixed. The slight increase in those first poured is probably owing to the lower temperature of pouring, due to exposure during preparation and skimming, and consequent more rapid setting in the mold.

The effect of rapid cooling is well known, and is used successfully with almost every metal or alloy. In the proper production of the steam bronzes it is of great importance and produces a marked effect, increasing the density, reducing the porosity and rendering the etched section much more uniform, causing a great reduction in the amount of liquation and the number of projecting points of the eutectic alloy. Two groups of test pieces were obtained and tested with the following results:

SHORT CYLINDERS.

Average specific gravity of specimens poured hot	8·661
“ “ “ “ “ “ cold	8·915

FLAT DISCS.

Average specific gravity specimens poured hot	8·595
" " " " " cold	8·598

showing a 3 per cent. gain as before for the short cylinders of small diameter, and practically no change for the larger sections. To determine the effect of maximum practical rapidity of cooling, a small casting was made in an iron mold, and compared with sand contact.

Specific gravity of casting poured in iron mold	9·285
" " " " " " sand	8·610

Increase due to rapid cooling, 7·2 per cent.

The appearance of the fracture was different; the grain was closer and the tensile strength was higher. Under the microscope the difference was apparent, there being much less liquation, without visible porosity and with great reduction in the number of projecting points of the eutectic.

Unless excessive internal pressures are used, high ultimate tensile strength is seldom needed, as it is customary to increase the section rather than sacrifice other qualities. When the strength is increased by the addition of aluminum or phosphorus, the expense of remelting the enlarged gates and risers becomes an important item, and there is additional risk of porosity in castings of variable section. Rigidity of form, on the other hand, is of great practical value, so that under strain the castings may not lose their original form or alignment. For all ordinary commercial uses of the steam bronzes, an ultimate tensile strength of from 27,000 to 30,000 pounds per square inch is sufficient, and to obtain this value as well as both homogeneity and solidity, careful and conscientious treatment in the foundry is required.

As has been shown, the characteristics of any one mixture of metals producing a steam bronze, vary with the conditions under which the castings are made. Authorities recognize this fact and give a maximum and minimum value of the specific gravity, because no absolute value can be taken. The location of the casting in the mold, the size of the section, the contiguity of large and small masses, as well as the conditions already referred to, affect the density and the homogeneity. In my investigations, the specific gravities have been determined by our fellow-member, Prof. A. E. Outerbridge, Jr., a statement which is a sufficient guarantee of accuracy. Many were repeated several times, and test pieces cut in halves, to ascertain if there might be any variation shown by smaller sections. The results may, therefore, be accepted as relatively correct and exact as applied to the specimens submitted. The investigations of these steam bronzes also include the position and location of the pattern in the mold and the methods of gating; where a large and small section are contiguous, it is advantageous to place the heavy part of the pattern, having the larger volume in proportion to surface, in a position where it shall be filled by the first poured and cooler metal; it has been found better in certain cases to place the heavier part above and then gate from the lower end of the smaller section. As the larger part is filled with metal at a lower temperature, it cools in about the same time or slightly in advance of the metal in the smaller section, producing a dense casting, free from shrink holes.

In conclusion, it may be said that in many important lines in which the steam or allied bronzes are in use, there are deteriorating agencies at work, acting both mechanically and chemically upon the exposed and vitally important surfaces, which in time destroy the usefulness of the device; the power of the metal to oppose these forces depends chiefly upon the homogeneity and density, and upon these depends the durability of the apparatus.

Finally, these saving qualities can be obtained only by the use of the microscope and the testing machine and retained by careful attention to every detail in the foundry.

DISCUSSION.

MR. G. H. CLAMER:—Mr. Kneass has brought out some very interesting facts relative to alloys which may be used for steam purposes, and their manipulation in the foundry, but he failed to make mention of one very important factor, which will produce a metal sufficiently dense to withstand the high pressures which such an alloy is called upon to resist. I refer to the admixture to such an alloy of a small quantity of lead. It has long been known by foundrymen that a mixture of a small quantity of lead will produce this effect, and, further, it facilitates the machining of castings which contain it. I know of a very interesting experience bearing on this subject, viz.:

In the time of the old bronze cannons, which were made from an alloy (known as "cannon bronze") of copper and tin, a certain founder had taken a government contract for the manufacture of quite a number of guns of this character. According to the specifications, the government inspectors were required to weigh the charges, see that they were charged in the furnaces and then the foundryman was held responsible for the castings. These guns were subjected to certain pressure, and, after repeated failures, the manufacturers, being familiar with the value of lead in the alloy, decided to have some molds made of the exact shape in which pure tin was marketed. One night they melted the tin which they had on hand, and added a certain small percentage of lead, then poured it into molds, and when the inspector came the next day he weighed the pigs, which he had no reason to suspect were anything else but pure tin. The mixture was then made up in the usual way, and to the utter surprise of the government officials the castings from that day all came up to the full requirements.

There has been another point mentioned by Mr. Kneass, viz., the difficulties which are sometimes encountered, due to the presence of the eutectic.

What is now known by the name of "eutectic" to the old founders was known as "tin spots," and it was with the idea of removing these that the old bell founders tried various expedients, notably the addition of metallic silver, etc.

In our daily production of alloys containing copper and tin, the presence of the eutectic can be observed. In casting ingots of phosphor-bronze, which contain 80 per cent. copper, 10 per cent. tin and 10 per cent. lead, its presence is very often manifested by the appearance of globules on top of the ingots. These, when subjected to analysis, are found to contain approximately 22 per cent. tin, 2 per cent. lead, 74 per cent. copper and perhaps 2 per cent. to 3 per cent. phosphorus. This quite likely is a complicated quadruple eutectic. It demonstrates that phosphorus in phosphor-bronze is contained almost entirely in the eutectic part of the alloy, and it is due to this that phosphor-bronze is so materially harder than alloys of the same composition which do not contain it.

PROF. A. E. OUTERBRIDGE, JR.:—There is one explanatory statement in Mr. Kneass' excellent paper to which I wish to offer a slight modification. He attributes the greatly increased density and finer texture of test samples of bronze cast in an iron mold, as compared with similar samples of the same bronze metal cast in a sand mold, entirely to the more rapid cooling of the metal when cast in the iron mold. I have made very many experiments in this direction, covering a period of sixteen years or more, and the result is that I attribute the phenomenon mainly to what I call "fluid compression."

You may ask what do I mean by fluid compression in this connection? I mean simply this: Certain alloys of metals expand with enormous force at the moment of cooling. It is due to this fact that we are enabled to obtain sharp castings. Pure copper, pure silver, pure gold, etc., do not give sharp castings, because they do not expand greatly at the moment of cooling.

When such an alloy as that referred to by Mr. Kneass is cast in a sand mold, it first fills the mold, and then when pouring has ceased it suddenly expands and forces the yielding grains of sand outwards in all directions, making a larger cavity than before. A skin of cooled metal forms immediately; then contraction of the mass begins to take place, the thick sections cool more slowly than the thin sections, giving rise to "segregation" and to spongy spots or porous places, while the whole texture of the congealed metal is of coarser grain than it would have been if it had been subjected to mechanical pressure when in a plastic state.

When this alloy is cast in a metal mold the expansion at the moment of cooling takes place as before, but encounters the rigid walls of the mold, and, therefore, *fluid compression of the molecules of the metal itself* takes place. The internal pressure is frequently sufficient to cause the fluid portion of the metal to burst through the "skin," formed on the upper surface of an open metal mold, where the casting has congealed by exposure to the air, forming pimples of eutectic alloy, and in some cases long filaments curling over in horn-like shapes are extruded.

On cutting a section, through an ingot or casting made in a metal mold, then polishing and etching, it will always be found much denser, more uniform in texture, and much more free from segregation, than the same metal cast in a sand mold, while the specific gravity is also considerably higher. Such metal is not necessarily harder than when cast in sand, though the "chips" are quite different in appearance. It may be likened to the difference in density and fineness of grain observed in a piece of pine wood that has been squeezed in a powerful hydraulic press, as compared with a piece of the same wood not compressed. Metallic alloys which have been subjected to this fluid compression show greatly increased tensile strength. These are facts not generally understood, all having important practical application in the metallurgical arts.

Mr. Kneass:—The chief advantage in the use of lead in steam bronzes is to reduce the length of the chip and the cost of machining, as stated in the paper; the percentage should be small, not exceeding 3 per cent. There is no doubt but that its presence adds somewhat to the solidity, but when a small amount of zinc is also present the function of the lead is to reduce the cost of finishing the castings. The Bureau of Supplies and Accounts of the Navy Department of the United States limits the lead in steam bronzes to 1 per cent., while the Bureau of Steam Engineering omits it entirely.

Referring to the experiments where castings were made in an iron mold, there is no doubt that fluid compression plays some part, but considerable investigation would be required to determine the extent. The theory suggested by Mr. Outerbridge is interesting, and may account for the unusually high density of this group of test pieces.

RECOVERY OF TIN FROM SCRAP.

The treatment of new tin scrap, known as "detinning," has become of considerable importance in the United States, and at least ten companies were actively engaged in this special branch of the industry during the year 1903. The average yield from tin scrap is approximately 2 per cent. of metallic tin. In addition, a large number of small concerns in the principal cities recover the tin from old tin cans and similar material by a smelting treatment in a furnace, the tin being obtained in the form of solder, which is either used as a basis for making new solder or is treated chemically to yield metallic tin or tin salts. The residue of scrap iron is generally utilized in the manufacture of sash weights and other castings of inferior quality of iron.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, December 21, 1904.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 21, 1904.

PRESIDENT JOHN BIRKINBINE in the chair.

Present, 92 members and visitors.

Additions to membership since last report, 14.

The major part of the meeting was devoted to the St. Louis Exposition.

The subject was introduced by Prof. Lewis M. Haupt, who gave a general historical sketch of the origin and development of exhibitions in general, and followed with a general description of the St. Louis Exposition, the latest and in many respects the greatest of them. His remarks were illustrated by a series of views of the grounds and buildings.

Mr. Samuel M. Vauclain, Superintendent of the Baldwin Locomotive Works, followed with a detailed account of the more important features of the exhibits in the Transportation Building. His remarks were devoted largely to the exhibits of locomotives and rolling stock, and were profusely illustrated with lantern photographs.

Prof. Carl Hering followed with some informal notes and comments on the electrical features of the exhibition.

Prof. L. F. Rondinella then read a paper on the making of long photoprints, with special reference to an improved machine of this kind, which he had devised, which he exhibited and described, and subsequently showed in operation. Several specimen prints, one of them 19 feet long (made in twenty minutes), were exhibited as the product of the machine, which was stated by the speaker to be capable of making a print 70 feet long.

The invention was referred to the Committee on Science and the Arts for investigation and report.

Mr. W. N. Jennings then exhibited and commented on some unusually interesting lightning photographs, showing the repeated striking of the tower of the City Hall.

Mr. Waldemar Lee, duly seconded, offered the following preamble and resolution, which, after some discussion, were adopted, viz.:

"Whereas, Alcohol is a necessary material in the manufacture of many important articles of commerce ; and

"Whereas, An important group of American industries has thus far been dwarfed by the lack of free alcohol in the arts and manufactures, and for the ostensible reason that it was difficult for our revenue authorities to prevent its use otherwise than for these purposes ; and

"Whereas, Competing nations, notably, Germany, France and England, find no difficulty in prescribing and enforcing regulations to prevent such use.

"*Resolved*, That in the opinion of the Franklin Institute it is the duty of Congress and our revenue authorities to afford our manufacturers equal facilities in this respect with those of competing nations, and at the same time benefit our agricultural interests by affording an increased use for our greatest cereal crop. We therefore favor the passage of the bill introduced by Representative Boutelle, H. R. 9,302."

The following nominations for officers, managers and committeemen were made, to be voted for at the annual election to be held on Wednesday, January 18, 1905, between the hours of 4 to 8 P.M., viz.:

For *President*	(to serve one year)	John Birkinbine.
" *Vice-President*	(" three years)	Washington Jones.
" *Secretary*	(" one year)	Wm. H. Wahl.
" *Treasurer*	(" ")	Samuel Sartain.
" *Auditor*	(" three years)	Wm. H. Greene.

For *Managers* (to serve three years).

Edwin S. Balch,
Walton Clark,
Thos. P. Conard,
Chas. Henry Howson,
Louis E. Levy,
Chas. Longstreth,
Isaac Norris,
Coleman Sellers.

For *the Committee on Science and the Arts* (to serve three years).

A. W. Allen,
Hugo Bilgram,
Amos P. Brown,
Frank P. Brown,
W. W. Canby,
Kern Dodge,
W. C. L. Eglin,
E. Goldsmith,
Lewis M. Haupt,
Lucien E. Picolet,
C. J. Reed,
Jas. S. Rogers,
Geo. P. Scholl,
E. Alex. Scott,
Coleman Sellers,
Harrison Souder,
H. W. Spangler,
A. H. Stewart,
D. Eppelsheimer, Jr.,
Martin I. Wilbert.

Adjourned.

Wm. H. Wahl,
Secretary.

Committee on Science and the Arts.

Abstract of proceedings of the stated meeting held Wednesday, December 7, 1904.

PROF. LEWIS M. HAUPT in the chair.

The following reports were adopted:

(No. 2327.) *The Glazier Fire Nozzle.* Bradley & Munson, New York.

ABSTRACT: This apparatus is the invention of John T. and Peter F. Glazier, of Indianapolis, Ind., and consists of a hose pipe and connections designed for the purpose of overcoming the difficulty of handling fire streams from hose lines under high-pressure service, and also for the purpose of directing a stream at a specific point continuously without demanding attention from firemen.

The apparatus is a brass play-pipe connected by a swivel joint to a curved waterway attached to a hose connection by a ball-bearing joint so that the play-pipe can be moved in two directions in planes at right angles to each other. In one style (having a single waterway) the stream from the hose after passing through the curve is delivered into a chamber with elliptical cross-section and thence through the play-pipe. In another style (having two curved waterways diverging directly above the ball-bearing joint) the water stream is again united in a well-shaped chamber and passes thence through the play-pipe. Either style can be directly coupled to one hose line, or can be attached to a Siamese hose connection, allowing two or more hose streams to be concentrated through the apparatus.

The report then proceeds to describe a series of tests with the apparatus, which exhibited an average loss of 10 pounds pressure above or below the curved arms, in high-pressure service.

The apparatus is adaptable to various fire department devices, such as monitor wagons, water-towers, and, above all, for use in connection with hose streams in a stationary position without attention of a fireman.

The report awards a Certificate of Merit to the inventors. (*Sub-Committee,* Chas. A. Hexamer, chairman; Wm. McDevitt.)

(No. 2341.) *Expanding and Flanging Machinery and Tools.* Luther D. Lovekin, Philadelphia.

ABSTRACT: These inventions are based on the well-known "Boiler-Tube Expander" introduced by Dudgeon, of New York, but embody many important improvements designed to increase the efficiency and durability of the tools and to adapt them to a much wider range of work. The inventions are covered by the following letters-patent of the United States: No. 723,289, March 29, 1903; Nos. 734,271, 2, 3, and 4, July 21, 1903; and Nos. 682,725, 6, September 17, 1901, granted to applicant. A full description of the Lovekin tools and machinery with illustrations will be found in the *Journal of the Franklin Institute,* June–July, 1904, to which reference may be made.

The report concludes as follows: "This system of expanding tubes undoubtedly possesses great merit, and in view of the great advantages conferred upon the shipbuilding and other important engineering industries thereby, and the great ingenuity displayed by the inventor in working out the system in its various forms and details, the Franklin Institute awards the Elliott-Cresson Medal to Louis D. Lovekin." (*Sub-Committee*, Thos. P. Conard, chairman; J. M. Emanuel, John Haug.)

(No. 2350.) *Instantaneous Automatic Water Heater.* Edward Ruud, Pittsburg, Pa.

ABSTRACT: This invention is one of many devices intended for domestic service, in which the opening of a hot-water faucet anywhere on the house line will speedily be followed by a continuous supply of hot water.

The operative mechanism consists of a coil boiler (of copper) supplied from the house distributing system and connected by means of a by-pass with a valve controlling the gas supply of the house service. This gas valve is actuated by the opening or closing of the hot-water faucets of the house water supply. This valve is so adjusted as to respond sensitively to the water pressure when this is thrown on or off by the opening or closing of a hot-water faucet in the house. A small pilot light, which is left burning constantly, serves the purpose of igniting the series of burners of the heater coil, through which the water supply must find its way to the point of consumption.

The report finds that this Ruud contrivance accomplishes its intended purpose satisfactorily and possesses advantages over others of its class in respect of greater freedom from clogging up of burners by dust, etc., and convenience of access for inspection and repairs. The award of the Edward Longstreth Medal is made to the inventor. (*Sub-Committee*, Charles E. Ronaldson, chairman; F. P. Brown, W. O. Griggs, I. M. Emanuel.)

The following reports passed first reading:

(No. 2331.) *The Burglar Immunity Company's System of Electric Protection.*

(No. 2345.) *The Flexible Compound Company's Products.*

(No. 2348.) *Mucklé's Elevator Safety System.* W.

Sections.

[*Abstracts of Proceedings of Stated Meetings.*]

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, held Thursday, December 1st, 8 P.M. Mr. G. H. Clamer in the chair. Present, 86 members and visitors.

The first paper of the evening was read by Mr. Samuel M. Vauclain, Superintendent of the Baldwin Locomotive Works, Philadelphia, on "Rolled Steel Car Wheels." The speaker made comparison between the old style chilled cast-iron wheel and the modern rolled steel wheel, and proceeded to describe the method of manufacture practised by the Baldwin Works. A free discussion followed, participated in by Messrs. J. S. Whitney, A. E. Outerbridge, G. H. Clamer, and the speaker. Mr. Strickland Kneass, of Wm. Sellers & Co., Philadelphia, followed with a brief paper on the "Physical Characteristics of Bronzes Used for Steam Purposes," which was discussed by

Messrs. Clamer and Outerbridge. The papers with discussion were referred for publication, and the speakers were given a vote of thanks.

Adjourned. I. EPPELSHEIMER, JR.,
Secretary.

ELECTRICAL SECTION.—*Stated Meeting*, held Thursday, December 8th, 8 P.M. Mr. Thomas Spencer in the chair. Present, 68 members and visitors.

Prof. W. S. Franklin, of Lehigh University, read a paper on "Long-distance Transmission Lines," which he illustrated with the aid of a number of models and photographs.

Mr. H. Clyde Snook, of the Roentgen Ray Manufacturing Company, Philadelphia, followed with a description of an improved "Ampere-Meter for High-Potential Currents," which he exhibited and demonstrated in operation. Both papers were freely discussed and referred for publication.

Adjourned. RICHARD L. BINDER,
Secretary.

CHEMICAL SECTION.—*Stated Meeting*, held Thursday, December 15th, 8 P.M., Dr. Robert H. Bradbury in the chair.

Prof. E. B. Voorhees, Director of the New Jersey Agricultural Experiment Station, New Brunswick, N. J , presented a communication on the "Sources of Supply and Methods of Manufacture of Phosphates and Potash Salts," illustrating his remarks by the exhibition of a large number of lantern photographs.

The speaker's remarks embraced an account of the occurrences and characteristics of the several important phosphate deposits in the United States, including especially those of South Carolina, Florida, and the more recently discovered beds in Tennessee. This was followed by an interesting account of the famous potash salt deposits of Stassfort. Discussed by Drs. R. H. Bradbury and W. J. Williams, and Mr. Waldemar Lee. The meeting passed a vote of thanks to the speaker.

Adjourned. W. E. RIDENOUR,
Secretary.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, held Thursday, December 22d, 8 P.M. Mr. C. H. Clamer in the chair. Present, 32 members and visitors.

The chairman presented Mr. Edward A. Uehling, of New York, who read a highly interesting paper on the "Fundamental Principles Involved in Blast-Furnace Practice." The paper was discussed quite fully by Prof. A. E. Outerbridge, Dr. Geo. P. Scholl, Dr. Edward Goldsmith, Mr. Walter Wood, Mr. Clamer and the author. (Paper and discussion will appear in due course in the *Journal.*)

The chairman expressed the thanks of the meeting to the author of the paper and adjourned the session.

WM. H. WAHL,
Secretary pro tem.

JOURNAL

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THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

Mechanical and Engineering Section.

Stated Meeting, held Thursday, December 1, 1904.

Rolled-Steel Car Wheels.

BY SAMUEL M. VAUCLAIN,
Superintendent of Baldwin Locomotive Works.

The requirements for car wheels have risen very rapidly during the last few years, and wheels which were at one time satisfactory are now taxed beyond their limit by the more severe service which is expected of them. The loads upon the wheels have increased from 50 to 100 per cent., whereas it has been impossible to increase the weight of the wheel in a like proportion because the limiting factors, such as frogs, switches, etc., were fixed before the modern 100,000-pound-capacity car came into use.

The manufacturers of chilled cast-iron wheels have been very successful in meeting the demands which have been made upon them, careful design and selection of the best mold and approved method of casting have accomplished much. The chilled-iron wheel is distinctively an American product, and we have occasion to feel proud of the achievements which have been made in the developments of this wheel. But the brittleness of the flange, inability to resist the heating effect of the brake shoe, shelly treads (as shown in *Fig. 1*), producing flat spots and the internal stresses induced in the casting of such a wheel have created a field for a wheel which would be free from these objections. This demand has been met by the introduction of the steel tired wheel, such wheels are manufactured with both plate and spoke centers. Steel-tired wheels of many designs have been made, their centers being of cast iron, cast steel and wrought iron and of both plate and spoke form. Those of wrought iron being very difficult to produce cheaply, to meet the competition of the world, because of our high-priced labor.

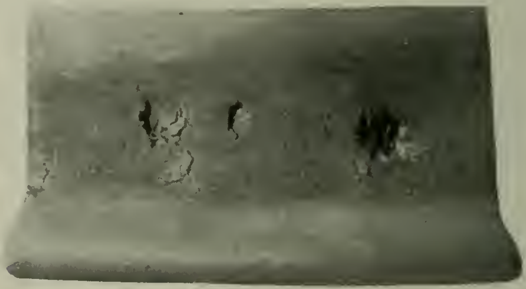

FIG. 1.—Sample of shelled tire.

Fig. 2 shows three stages of the process of making wrought-iron spoke centers. The spokes are made by bending pieces of iron in the form of a triangle, these are fitted into a round ring, the hub is then filled with iron and the wheel is heated and hammered under dies. *Fig. 3* shows two stages of the manufacture of wrought-iron plate centers.

Standard wheels of the types so well known and in use for several years under passenger and other high-priced equipment are too expensive, at least they are so considered, to put under freight equipment.

Even these wheels suffer from shelly spots on the tires, or a variation in the density thereof, unless the utmost care and expense attend their manufacture.

Fig. 4 shows an etched section of a defective tire and of a good tire, the good tire being dense and perfectly homogeneous, whereas the defective tire shows a structure which is not uniform in density and which contains other structural defects.

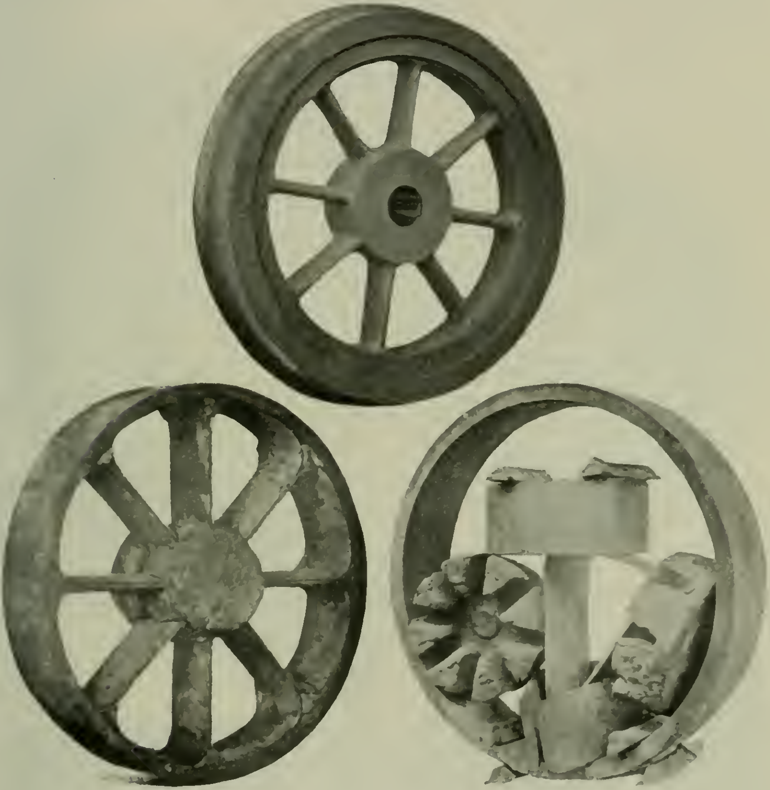

FIG. 2.—Forged steel-tired spoke wheel.

It is thus we find an aching void in the wheel business. We must be able to produce a wheel, safe, durable and sufficiently low in price to compete with and eventually supersede the chilled cast-iron car-wheel that has so long held sway in this country.

Fig. 5 shows the etched section of a long ingot. This is the base of all processes necessary to make a first-class solid forged, high carbon, rolled steel wheel, cheap enough to compete with cast-chilled wheels, and good enough to compete with the high-priced steel-tired wheels. The process of manufacture is simple; the ingot is cut into sections, as shown on *Fig. 6.* Each section is of sufficient weight to make a wheel, and the upper or segregated section is discarded.

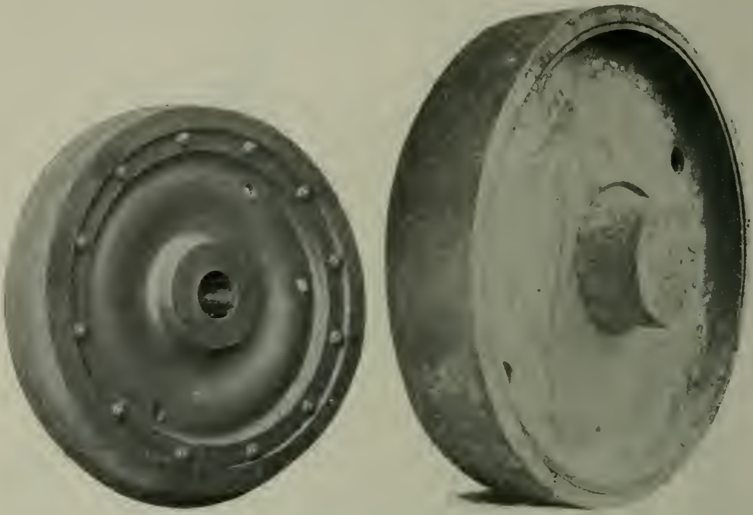

FIG. 3.—Forged plate steel-tired wheel.

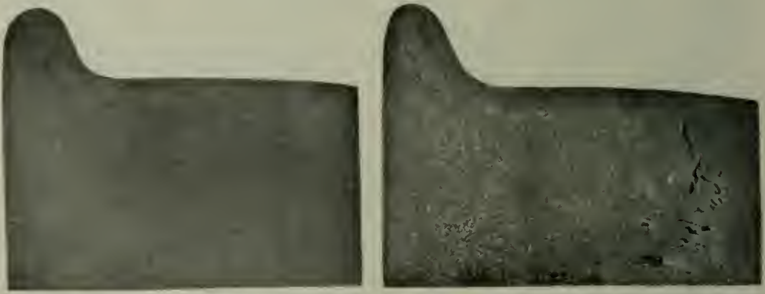

FIG. 4.—Section of good and poor tire.

Fig. 7 shows this process, the ingot being handled by an immense and powerful manipulator, or mechanical man. This device is almost human in its action, reaching into the furnace, taking out a blank and deftly putting it under the press. Each of these sections is then pressed into shape under a huge 5,000 ton hydraulic press, the blanks being handled by mechanical means, as shown in *Fig. 8.* From there by overhead cranes the blank is transferred to the rolls, where it is subjected to enormous pressure and revolved at a high rate of speed, emerging a perfect wheel.

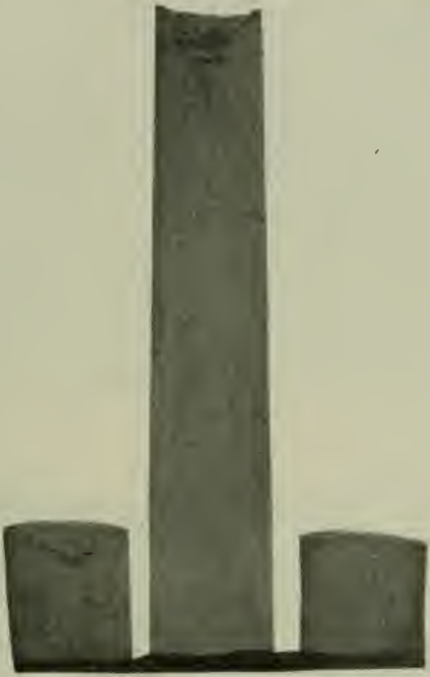

Fig. 5.—Cross section of ingot.

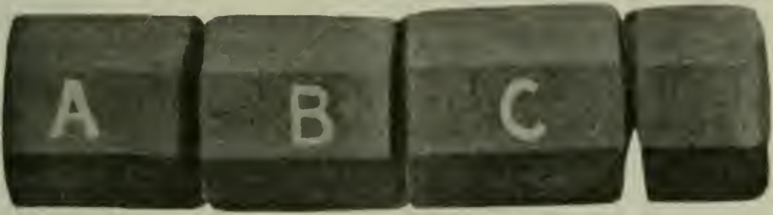

Fig. 6.—Blooms from which wheels are rolled.

The method of rolling and arrangement of rolls is shown in the diagram on *Fig. 9*, from which it will be seen that

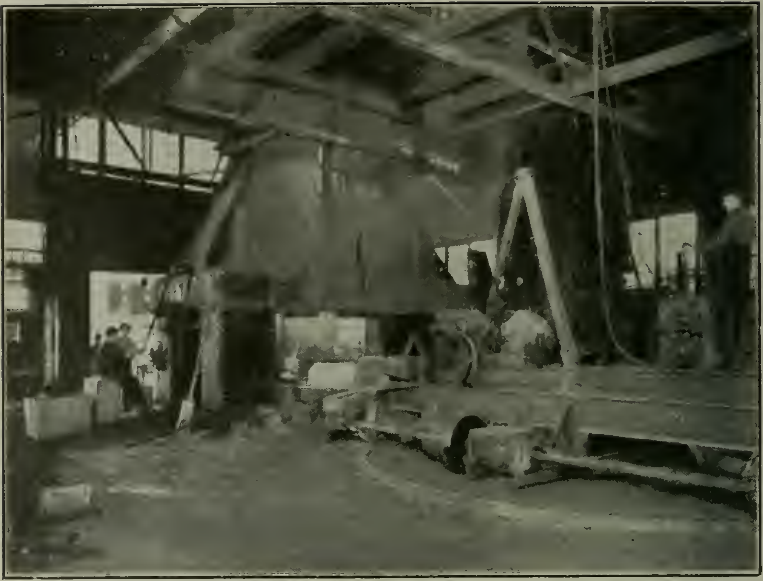

FIG. 7.—View of manipulator.

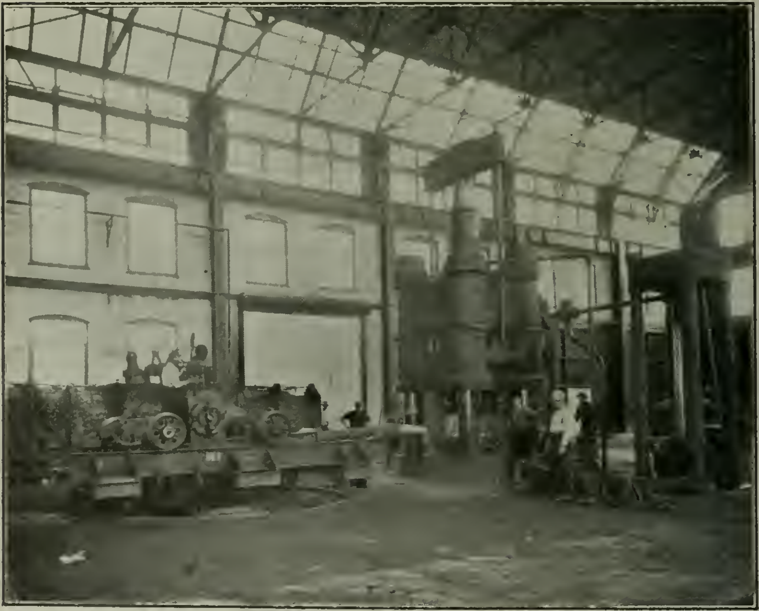

FIG. 8.—View of 5,000-ton press.

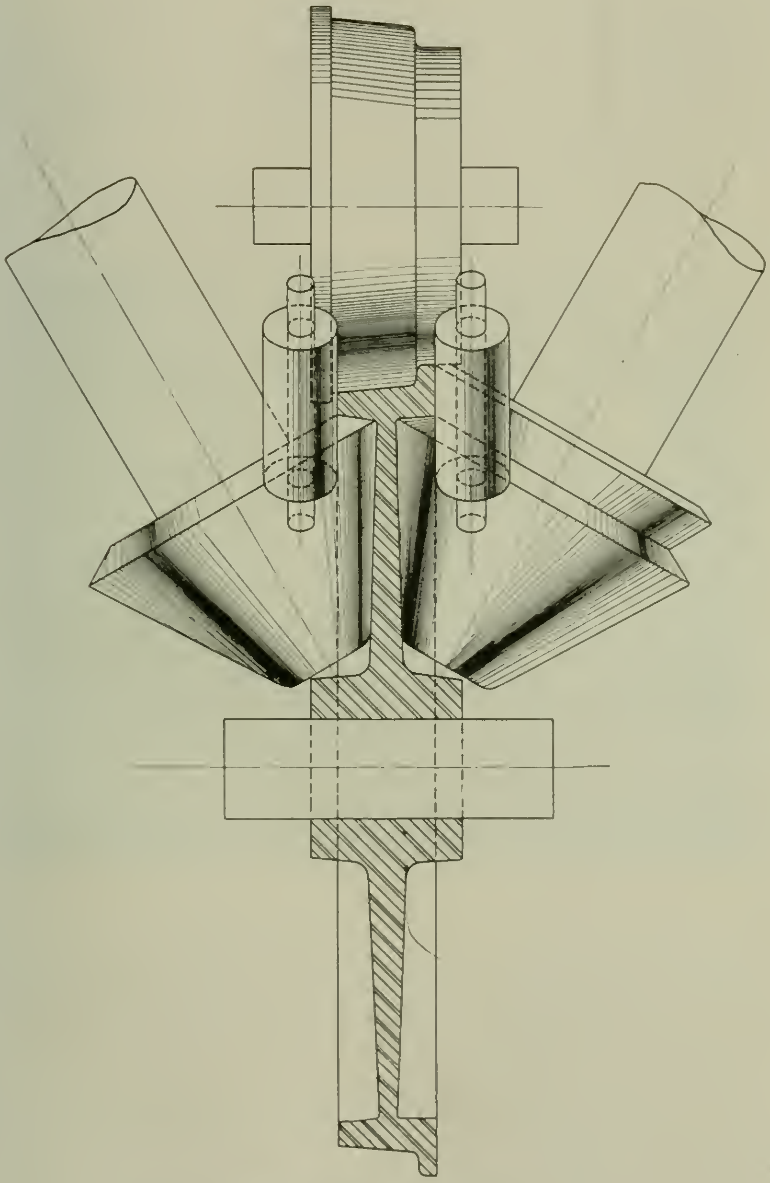

FIG. 9.—Diagram of rolls.

the arrangement is such that thorough and heavy work can be put on the tire of the wheel.

If we desire the plate of these wheels to be of the dished or curved form the same is easily accomplished by placing it in the 500-ton press and gently squeezing it into shape, as shown in *Fig. 10.*

Fig. 11 shows three etched sections of a forged wheel, the quality of the material is unquestionable and the wheel possesses all the characteristics of the good tire and none of those of the defective tires, which I have already shown and which I am again showing on the screen for the purpose of comparison.

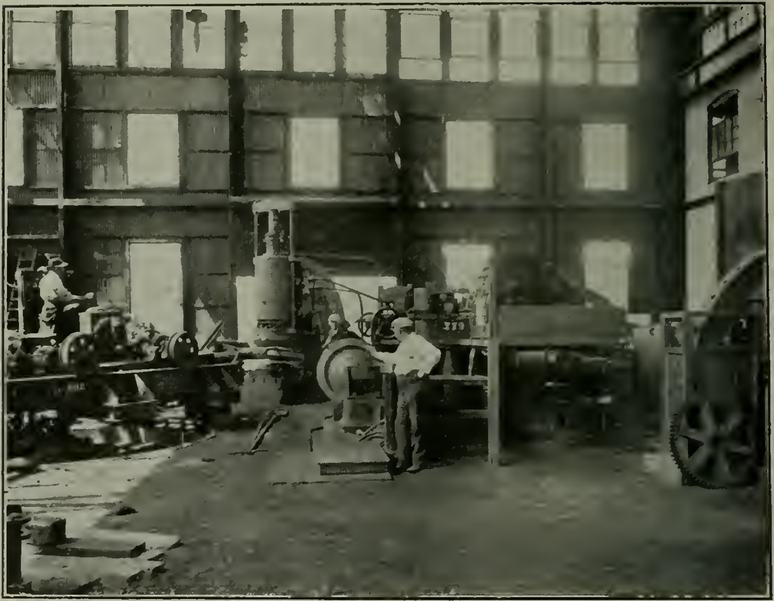

FIG. 10.—View of rolling machine.

The judgment formed by an examination of the etched section is confirmed by the results of the physical and chemical tests.

Fig. 12 shows sections of wheel from which drillings were taken for analysis, the results are surprisingly uniform and indicate the greatest uniformity in the wheel. Tests

CHEMICAL ANALYSES.

Test.	Carbon.	Silicon.	Phosphorus.	Manganese.	Sulphur.
Flange	·610	·268	·043	·87	·050
Tread . .	·614	·268	·042	·90	·048
Face . .	·620	·267	·041	·86	·052
Rim . . .	·614	·270	·042	·91	·052
Plate . .	·602	·265	·043	·89	·051
Hub	608	·265	·042	·86	·048

PHYSICAL TESTS.

Test.	Size of Test.	Elastic Limit.	Ultimate Strength.	Elongation.	Reduction of Area.
	Inches			Per Cent.	Per Cent.
Flange .	2 x ·619	50,300	126,600	12·0	19·0
Tread . .	2 x ·619	50,600	124,600	10·0	12·0
Face . .	2 x ·619	52,600	121,000	10·0	13·0
Rim	2 x ·619	52,000	121,300	12·0	16·3

CHEMICAL ANALYSES.

Test.	Carbon.	Silicon.	Phosphorus.	Manganese	Sulphur.
Flange . .	640	·175	·042	·86	·050
Tread	·650	·177	·042	·86	·050
Face	·650	·180	·045	·86	·050
Rim . . .	·654	·175	0·44	·85	·051
Plate . . .	·660	·180	·046	·84	·049
Hub	·666	·180	·044	·84	·050

PHYSICAL TESTS.

Test.	Size of Test.	Elastic Limit.	Ultimate Strength.	Elongation.	Reduction of Area.
	Inches.			Per Cent.	Per Cent.
Flange .	2 x ·619	52,000	129,000	14·0	20·0
Tread . .	2 x ·619	51,600	124,300	10·0	13·0
Face . . .	2 x ·619	52,300	128,600	10·0	15·0
Rim	2 x ·619	51,300	124,000	11·0	16·6

have also been made by supporting the wheels horizontally upon a ring underneath the face of the tread and allowing

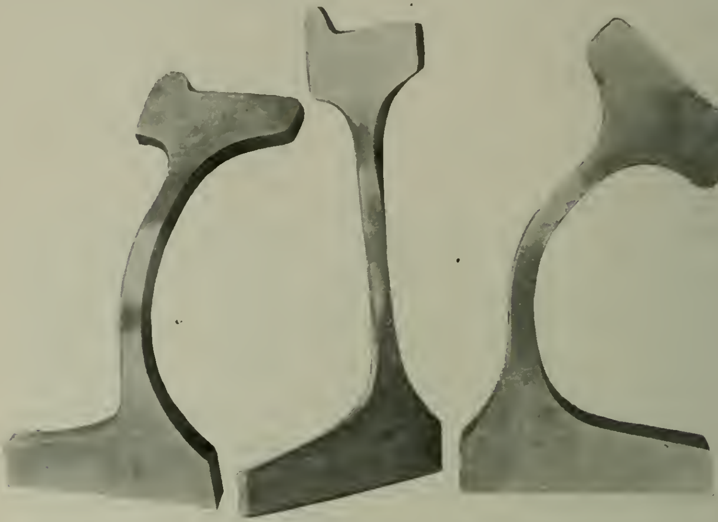

FIG. 11.—Etched sections.

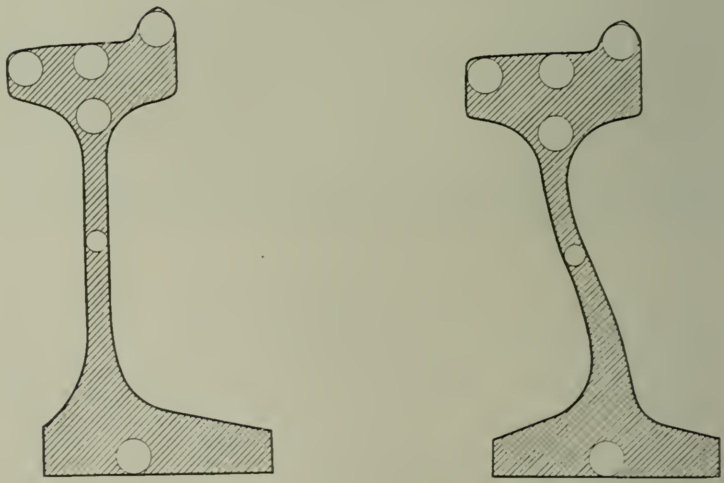

FIG. 12.—Results of chemical and physical tests.

a weight of 2,240 pounds to strike the wheel from various heights. It took thirteen blows to break a 36-inch wheel, eight of the blows being from a height of 30 feet.

Another wheel was tested in running position, and striking with a weight of 2,240 pounds it took seventeen blows, nine of them being from 25 feet, to fracture the wheel from rim to hub.

Fig. 13 shows a wheel after it has been subjected to this test and it at once illustrates the severity of the test and the ability of the wheel to resist any stress which it is liable to encounter in service. It is perfectly clear that the use of this wheel would banish broken flanges from the list of causes leading to wrecks and damage to property.

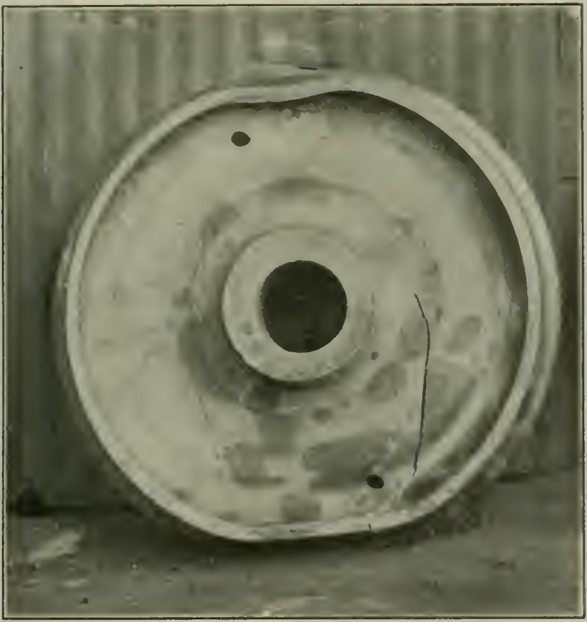

FIG. 13.—Rolled wheel after drop test.

One of the most severe tests that can be imposed upon the chilled-iron wheels is that generally known as the Thermal Test. This consists in pouring a ring of molten iron $1\frac{1}{2}$ inches thick and 4 inches deep against the tread, no cracks to develop within two minutes. This test is designed to secure a wheel which will not crack by the heat developed by the application of the brake shoes, and it is considered by manufacturers of chilled-iron wheels to be a very severe requirement. A number of rolled wheels have been subjected to this test without injury to them. The heat from a ring of metal 4 inches wide in place of 2 inches had no further effect than to cause the rim to expand and to draw the hub down slightly. No fracture was produced and the heat given out by the molten iron was sufficient to heat the tread for 2 or 3 inches to a dull cherry. After withstanding this test there need be no fear of breakages as the result of heating of the tread by application of brake shoes.

Now then as to the approximate value of these wheels as compared with cast chilled wheels of the very best material and manufacture. The comparison of the cost per 10,000 miles of the two types of wheels is shown in the following statement:

SOLID ROLLED WHEELS.

Cost of pair of rolled wheels	$54 00
Cost of four turnings	2 40
Cost of four removals and applications	2 40
	$58 80
Less scrap value	8 75
Net cost	$50 05

Mileage, 350,000.

Cost per 10,000 wheel miles, $1.43.

CHILLED-IRON WHEELS.

First cost of pair of chilled-iron wheels	$18 00
Cost of boring and mounting	80
Cost of removal and application	60
	$19 40
Less scrap value	5 80
Net cost	$13 60

Mileage, 80,000.

Cost per 10,000 wheel miles, $1.70.

It is usual for the railroads to determine the average cost of wheels by dividing the total yearly cost by wheel mileage made during that year. The statistics vary from 1·65 to 1·78, the average closely checking the foregoing estimate.

The natural field for the rolled wheel is:

(1) The severe service of engine and tender trucks, in which steel-tired wheels are now exclusively used.

(2) Passenger-car equipment, in which the element of safety plays an important part.

(3) Heavy freight-car equipment, for which the chilled-iron wheel has proved inadequate.

The wheels, however, are adaptable to lighter service, and statistics indicate that it would be profitable to employ them in street-car service.

The following statement shows the cost of maintenance of wheels in street-car service in various parts of the United States. These figures are practically based upon the use of the usual type of chilled wheel:

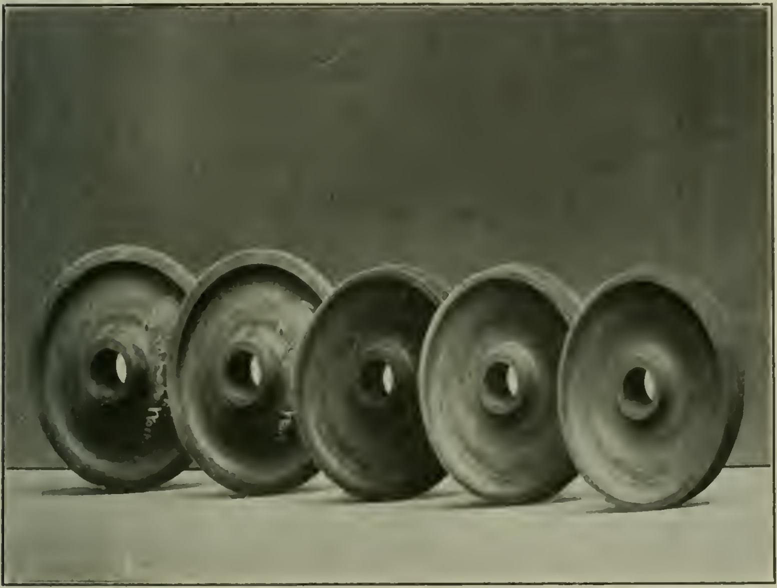

FIG. 14.—Rolled-steel wheels.

	Per 10,000 Miles.
Northwestern	$1 61
Pacific Coast	1 15
Middle-West	2 14
Chicago	3 04
Canadian	3 04
Philadelphia	1 65

The roads carrying the greatest number of passengers will generally show the greatest cost, as the constant braking necessary because of frequent stops and slipping resulting from rapid acceleration is very hard on the chilled-iron wheel. By the rough usage at many crossings many wheels are put out of service by chipping off the flanges. The rolled wheels are entirely free from this defect and their adoption by street railway companies should prove to be very economic. Progressive street railway managers have been quick to recognize the advantages that the steel wheel possesses over a cast iron one, and even the greater expense of the solid forged steel wheel has not deterred its introduction, and it is the general opinion that marked economy has resulted therefrom.

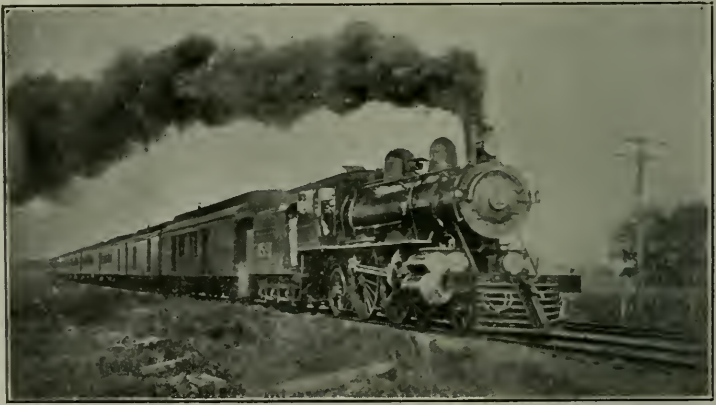

FIG. 15.—Rolled wheels in service.

We are already making solid forged steel wheels for this service in large quantities.

Fig. 14 shows a group of solid forged and rolled wheels for railroad service, the fine appearance of these wheels can be seen from this photograph.

As the mighty oak had its origin in the small acorn, so the great railroad systems of to-day rest upon the stability of the flange of a car wheel.

Upon this small section of metal, about $1\frac{1}{4}$ inches square, depend the lives of millions of passengers and the value of merchandise of incalculable price. Passengers amid the comforts and luxuries of our modern service hardly realize the vital importance of this piece of metal; but engineers and railroad managers do, and they have been directing their best endeavors to this most vital element of railroad equipment.

DISCUSSION.

MR. G. H. CLAMER:—Perhaps few of us, who are not directly connected with the operation of rolling stock, realize the large proportion of the railroad wrecks which are directly due to broken flanges. In former years when the equipment was light, speeds not so great, the cast-iron wheel did good service, but with the advent of the 100,000-pound capacity car, the cast-iron wheel, as formerly made, was found to be inadequate for the service. The old design of wheel was transformed, the flanges made as thick as possible, etc., but even so, they were found wanting.

The safety of the traveling public depends so much upon the wheel that railroad men have recognized for some time the desirability of using steel for this purpose. On passenger equipment it has become almost universally the custom to use a steel-tired wheel, but this is rather an expensive affair, and presents several defects which are perhaps not inherent in the wheel we see before us.

A steel wheel, forged directly from the solid ingot, at least, theoretically, presents the best kind of structure for the service. It is only a question of producing a wheel of this kind at a satisfactory price, and to show that it will compare favorably in operating cost with wheels now on the market, to create a great field for it. It is a difficult matter to make railroad people understand that an article which is high in first cost will be cheap in the end. This evidently applies to the product in question.

Mr. Vauclain has shown, although the steel wheels are softer than chilled cast iron wheels, nevertheless, the rate of wear is very much slower. The same holds good on bearing metals. It has long been the prevailing idea that it was necessary to have a hard bearing to resist wear, but that such is not the case has been amply proven by the fact that additions of large percentages of lead to the former copper and tin alloy has led to far better results, in not only anti-frictional but in wearing qualities. This fact was first brought out by Dr. Dudley, who made long series of tests fifteen or twenty years ago, in which he compared in actual service the wearing properties of copper and tin and copper, tin and lead alloys, with varying percentages of the different metals. Without going into the details of these experiments, suffice it to say, the following general conclusions were reached:

(1) The lower the content of tin, the slower the rate of wear.

(2) The higher the content of lead, the slower the rate of wear.

We perhaps all know that tin added to copper greatly increases its hardness, but it will be seen that both these conclusions have been drawn from alloys which were softer than the one which had hitherto been used as standard, viz: copper and tin, with 10 per cent. tin.

If hard metal is used for bearings or car wheels, whichever it may be, the effect due to abrasion is, the particles instead of being elongated are flattened out before being worn off, and are simply broken down and split off at a rapid rate. There is no doubt of this, and it is only a question of time before this will be thoroughly understood.

PROF. A. E. OUTERBRIDGE:—In view of the contemplated substitution of rolled steel car wheels for chilled cast-iron wheels in freight-car service, I wish to ask Mr. Vauclain whether any comparative tests have ever been made, to his knowledge, of the difference in rolling friction on the rail between steel wheels and chilled cast-iron wheels?

My reason for making this inquiry is because I remember a case in point which happened a number of years ago. A coal mine located in a mountainous district was equipped with coal cars, carrying perhaps 10 tons each; these cars were drawn up grade to the mouth of the mine by the mine locomotives, and then ran by gravity down the mountain. The system of braking was very crude, simply "choking" and "skidding" a sufficient number of the spoke wheels, which were chilled cast iron. The number of wheels which cracked, especially in cold weather, caused by heating due to the skidding, induced the proprietors to experiment with cast-steel wheels in place of chilled cast-iron wheels. They found, greatly to their surprise, that the mine locomotives could not pull as many loaded cars up the incline when equipped with cast-steel wheels as they did with chilled wheels, all other conditions remaining the same, and I was informed at the time that this difference was attributed to difference in friction between the wheels and the rail. The company decided not to adopt cast-steel wheels.

My recollection is that a locomotive pulled twenty-eight loaded cars equipped with chilled cast-iron wheels out of the mine without difficulty, and could barely pull twenty-six precisely similar cars equipped with cast-steel wheels, though I do not vouch for the exactness of these figures. If such a marked difference existed in the case mentioned, where the load on each wheel was comparatively light and the speed comparatively moderate, how much greater would it be in the case of the modern very heavy equipment and high speeds in freight service to-day?

A difference of 10 per cent. in hauling capacity of a locomotive, due to difference in rolling friction between steel wheels and chilled cast-iron wheels and the rail, would be a serious matter in freight-car service.

I am of the impression that it is an established fact that the brakes grip a steel wheel more tightly than they do a chiled cast-iron wheel at equal pressures, due to difference in friction.

MR. J. S. WHITNEY:—What is the weight of a 33-inch rolled steel wheel designed for same service as a 600-pound 33-inch cast chilled wheel?

MR. VAUCLAIN:—About 675 pounds.

MR. WHITNEY:—What Mr. Outerbridge has said suggests another observation and inquiry. The wear of the *tread* of a well chilled cast-iron wheel is due to the action of the brake, which in time removes the surface, and if the metal is not of proper quality, causes "shelling out." The rolling of the tread over the rail does not cause wear, unless there is not sufficient depth of chill, or the chill is too soft. But the wear of the *flange*, which is more important as to safety, is due to the friction of the side of the flange against the side of the rail, which reduces the thickness, and tends to breakage. As the steel tire must be of the same quality throughout, and can be no harder than is consistent with strength, while the chilled wheel can be made hard on tread and flange while the body of the wheel is soft and strong, it has always been found that the flange wear is greater in the tire than in the wheel, under same conditions. This, of course, makes necessary several re-turnings of tire, to form new flange.

I would ask, what is the experience with the rolled-steel wheel, having, as Mr. Vauclain says, an almost uniform chemical analysis, in this respect?

MR. VAUCLAIN:—A consideration of the various resistances which a locomotive overcomes in hauling a train will at once show that the rolling friction of the wheel plays but a minor part in the total resistance of the train. The total resistance is composed of that due to head or wind, to journal friction, to curvature, to acceleration or overcoming the inertia of the train, and to the grade, which is usually greater than all the others combined. The resistance due to these items is all independent of the rolling resistance of the wheel.

In designing engines no attention is paid to whether the cars of the train are to be equipped with chilled iron or steel-tired wheels, and an extensive series of experiments which I made upon train resistance as well as those made by various railroad companies have failed to show any difference in drawbar pull of a train equipped with steel-tired and chilled-iron wheels respectively.

The wear of the flange is usually greater than that of the tread, because in the former case there is sliding as well as rolling friction, whereas in the latter there is rolling friction only and the abrasive effect of the former is much greater than the latter. While the rolled wheel is of a uniform analysis the strength increases with the hardness. The ductility, however, decreases with the hardness, but no matter how hard the wheel be made, its ductility will always be greater than that of a chilled-iron wheel. The physical tests which I have made show this clearly, giving a tensile strength of 120,000 pounds per square inch against 35,000 pounds per square inch for a chilled-iron wheel. The flange wear of rolled wheels is the same as that of a steel-tired wheel, which is generally recognized to be less than that of chilled-iron wheels. In opening the discussion Mr. Clamer has clearly shown that a good wearing metal is not necessarily a hard one, and I have personally known tires to wear rapidly not because they were too soft, but because they were too hard.

RECORD HIGH-PRESSURE GAS WELL.

A gas well in the Nineveh region of Greene County, Pa., has shown what may be said to be the highest pressure ever observed in any natural gas well. The well struck the Campbell's Run oil sand, and, though the volume of gas was relatively small, the rock pressure finally passed the limit of the gauge, which was 1,500 pounds per square inch, and blew off the 2-inch pipe by which the well was shut in. As this pipe was supposed to be tested to 2,000 pounds, the ultimate pressure shown by the gas was probably not less than 1,600 pounds per square inch. A well in Lewis County, W. Va., has a record of 1,125 pounds per square inch, which is the highest known in that State.—*Iron Age.*

STEAM TURBINES FOR BALTIMORE ELECTRIC POWER.

An interesting feature of the recently announced developments in Baltimore electric power is the exclusive adoption of steam turbines as the prime mover. A contract recently closed by the Baltimore Electric Power Company with the Westinghouse Machine Company provides an initial equipment of 4,000 kilowatts in two generating units of 2,000 kilowatts each. A Westinghouse electrical equipment, complete and modern in every particular, has also been contracted for. Officers of the company state that the power plant will embody the latest developments in steam and electrical engineering. Being located outside of the congested districts of the city, all the boilers and heavy machinery will be on the ground floor. Floors and roofs will be of steel-concrete construction. The steam turbine plant will operate with a boiler pressure of 175 pounds and a superheat of about 100° F. A high vacuum condensing system will be installed, capable of sustaining a vacuum of 28 pounds at full load on the plant. The plant in its entirety has been designed on the separate unit plan, which virtually consists of a number of distinct power plants placed side by side, each entirely separate from the other, but each capable of helping out the other in case any link in the system should be disabled. This holds good through the entire apparatus, from the coal pile to the customer's building. In addition to this precaution against interruption of service, which is thus insured, the company will install a large storage battery which will ordinarily "float" on the system. The construction work is already under way and will be pushed as rapidly as possible in order that the plant may be complete in all respects and running smoothly by July next.—*The Iron Age.*

ELECTRIC FURNACE CONSTRUCTION.

An interesting example of the introduction of electro-chemical methods into old industries is offered in the manufacture of pure artificial corundum. The Norton Emery Wheel Co., an old-established firm, with its main works at Worcester, Mass., purchased, several years ago, from the Ampere Electrochemical Co., the patent of C. B. Jacobs for fusing bauxite in an electric furnace, thereby producing a pure artificial corundum. The fused charge is allowed to cool slowly, when it acquires the hardness of corundum and the toughness of emery, and is suitable for wheels, stones, and all the various uses of an abrasive. The process is worked in a plant of the Norton Emery Wheel Co. at Niagara Falls. A rather extended and interesting exhibit at the St. Louis Exposition showed that the process is in a state of very healthy development.

A patent granted on November 22d to A. C. Higgins, general manager of the Norton Emery Wheel Co., is evidently intended for the special purpose of making artificial corundum, or, as it is called, alundum; but is of more general interest since it shows how, by judicious furnace design, any special refractory lining with its troubles may be avoided. His furnace consists essentially of an iron shell forming the outside of the crucible with suitable means for applying water on the outside of the shell to all its parts in a continuously flowing stream or blanket, and conducting it away at the base. The portion of the charge in immediate contact with the cool shell solidifies and thus forms a lining for the rest of the molten mass. The lining consists, therefore, of solid alundum. Similar linings have been used with success in other electric furnace industries.—*Elec. World.*

GAS TURBINES.

It was inevitable that the success of the steam turbine should lead to an investigation of the problem of the gas turbine; for it is natural to argue broadly that the results obtained with one gas will be obtained with any other, unless, indeed, some radical difficulties inherent in the gas or in the mechanism employed for its expansion should be found to stand in the way. The prospects for the early development of the gas turbine were discussed recently in a paper read before the British Institute of Mechanical Engineers, and, according to the author, those prospects are not very bright. Of course, one of the chief difficulties is the high temperature of the gas, which necessitates, if the temperature is to be reduced to a degree that is not injurious to the cylinder, the carrying away of a large amount of heat by the cooling water. If it were attempted to dispense with cooling water, or to use only as much as would cause a moderate reduction of the temperature, the rotating parts of the turbine would have to run red hot, and there is no material known to the engineering art to-day that would hold together at such high temperature, if subjected to the great centrifugal forces that would be developed.—*Scientific American.*

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, January 18, 1905.

A Menace to the New York Harbor Entrance.*

By Lewis M. Haupt, C.E.

> "These restless surges eat away the shores
> Of earth's old continents; the fertile plain
> Welters in shallows, headlands crumble down,
> And the tide drifts the sea-sand in the streets
> Of the drowned city."
> From "A Hymn of the Sea."
> Wm. Cullen Bryant.

At the Buffalo meeting of this association, in 1886, the writer had the honor of submitting a paper on the "Problem of the New York Entrance," in which was set forth the peculiar physical conditions existing on the bar stretching from Sandy Hook to Coney Island and suggesting a method of so modifying the ebb current passing out at Gedney's Channel, as to increase the depth by natural erosion.

At that date the limiting depth in this, the deepest natural channel, was 23·3 feet at mean low water, which, with a mean tide of 4·8 feet, gave 28·1 feet at high stages, so that vessels drawing 27 feet have passed over it at extreme high water, prior to improvement by dredging. In 1884 a report was submitted to Congress urging the enlargement of the channel to a width of 1,000 feet and depth of 30 feet by dredging at an estimated cost of $970,000, as follows:

Improving Gedney's Channel for 30 ft., M.L.W. . .	700,000 c. y., @ 50 cts.
Improving Main Channel for 30 ft., M.L.W. . . .	1,550,000 c. y., @ 40 cts.

and it was expected that these channels would be "self-sustaining for many years." The Board of Engineers dissented from this view, however, and stated that it had "little expectation that anything more than temporary relief could be obtained from dredging on a bar exposed to the full force of the Atlantic, and hence cannot recommend that method for a permanent improvement." It therefore suggested a dike extending in a S.-S.E. direction from Coney Island at a cost of about $5,000,000 or $6,000,000. As this dike would have closed the Coney Island, Fourteen Foot and East Channels and would have reduced the tidal ingress, it was not built, and the method of dredging alone was adopted. The board was fully cognizant of the fact that the sand was being moved from the adjacent shore of New Jersey and Long Island into the Lower Bay, as indicated by the spits at Sandy Hook and Coney Island; but the extent of this movement does not appear to have been very fully considered, although an important factor in the relative cost of creating and maintaining the channels. Especially is this true in view of the greater demands which modern vessels are exacting as to capacity and draught. Instead of 30 feet depth and 1,000 feet width, there are now required 40 feet and 2,000 feet, respectively.

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*A paper read at the annual meeting of the American Association for the Advancement of Science, held at Philadelphia, December 26-30, 1904.

It has also been found necessary to maintain the 30-foot channels by dredging at an annual charge of about $50,000, with no resulting increase of depths, so that in 1899 the project of opening a more direct channel via the East or Ambrose passage by dredging to a depth of 40 feet and a width of 2,000 feet was approved by Congress, provided the cost should not exceed $4,000,000 for the removal of the 42,500,000 cubic yards then in place.

Under the 30-foot projects the amount expended up to July 1, 1904, was $1,967,111.82, or about $1,000,000 more than the estimate even at the very high unit prices of 40 and 50 cents per yard.

Under the 40-foot project, to same date, there has been expended $1,223,498.52, and "11,944,131 cubic yards have been removed." From this statement it appears that the general cost has been 10¼ cents per yard in the Ambrose Channel.

In the report of the board, composed of Generals J. C. Duane, Henry L. Abbot and C. B. Comstock, three of the most experienced members of the Corps of Engineers, it was stated that the movement of sand towards the New

York entrance was manifested by the "form of Sandy Hook, a sand spit about 5 miles long, which has been slowly built during past ages by this northward movement of sand along the New Jersey shore. It appears to have reached a limiting length . . . and in the last 145 years its length has varied only about 2,700 feet. . . . An examination of the charts of Coney Island show that its western end is moving westward as sand is moved to it, the motion of its 18-foot curve amounting to 800 feet between 1835 and 1881."

Unfortunately this report does not appear to state the probable amount of material carried on to the bar by these two littoral movements. It is to set forth the great importance of providing for this menace to the entrance in the near future that some attention will be given to it in this paper. While physicists may be more especially interested in the vertical movements of the earth's crust as suggested in the recent paper of Prof. J. W. Spencer on the "Submarine Great Cañyon of the Hudson River," these internal forces do not appear to have sensibly affected the depths of the channels for commercial purposes within the range of modern records, so that the investigation of the volume and rate of drift will be confined to its horizontal littoral transportation.

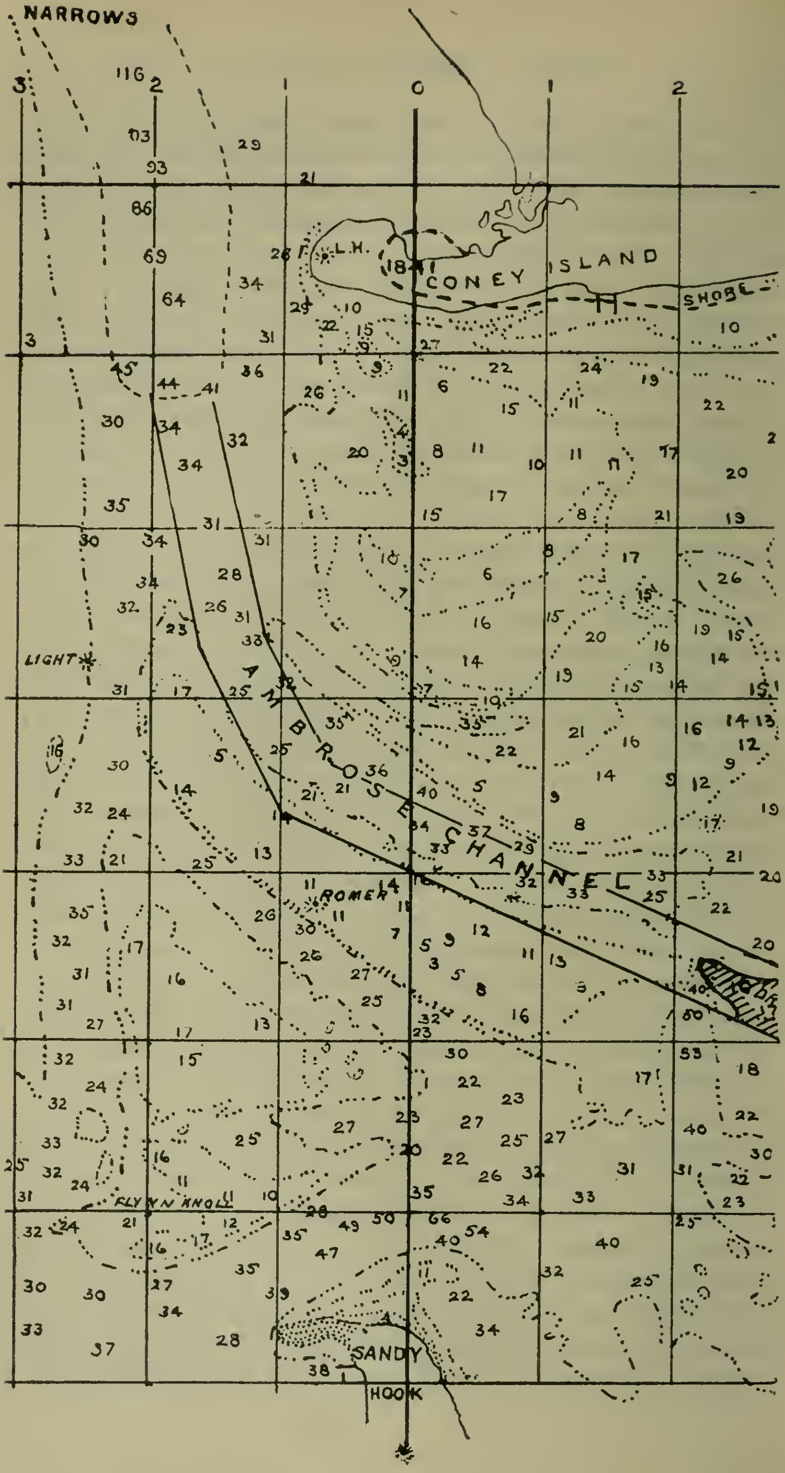
For this purpose the British, Dutch, Swedish and Spanish charts of the early explorers and settlers of the seventeenth century are found to be of no value, being apparently merely a collection of itinerary sketches of the general conformations of the coast, as seen from their vessels. Neither are movements which have passed their climaxes and reached a condition of equilibrium, or which are undergoing a transition under the new conditions which previous cycles may have imposed, as exemplified in the successive hooks which characterize the peninsula of Sandy Hook, where the third reflex spit is now forming.

Data.—An early colonial map of 1626 shows Sandy Hook under the name of Goodwin's Point, after whom the Lower Bay was also named, but it gives no geographical positions. The first charts of value for comparative study to which the writer has had access are those in the American Atlas, published by Wm. Faden, Charing Cross, London, in 1779, and collated by British officers during the Revolution. One of these, by Lieutenant Bernard Ratzer, of the Sixtieth Regiment, drawn from a survey of 1769, shows the New York Bay and Long Island on a scale of 6·6 miles to an inch. Another, being a detailed survey of the Hudson River and its mouth, published October 1, 1776, is on a scale of 4 miles to an inch, and a third, by Claude Joseph Sauthier, representing the entire State in sections; scale about 5 miles to an inch; was published in 1779. These three have been reduced to the same scale of 5 miles to the inch and superimposed for comparison as to position of shore lines. The discrepancies, smallness of scale and uncertainty of dates are such as to render them of comparatively little value, but they show the progressive movements of the inlets to the bays on the south shore of Long Island and the opening and closing of the breach at the mouth of the Shrewsbury River, N. J. Also the beginning of the outer beach, now covering "Rockaway Neck" and Jamaica Bay, and threatening the New York Bar. The State map of 1779 makes the distance from the Battery of New York City to Sandy Hook Light only 14 miles, instead of nearly 17 as given by the Coast Survey charts, thus discrediting its accuracy and confining this investigation to the later and absolutely reliable charts of the U. S. Coast and Geodetic Survey and those of the U. S. Corps of Engineers.

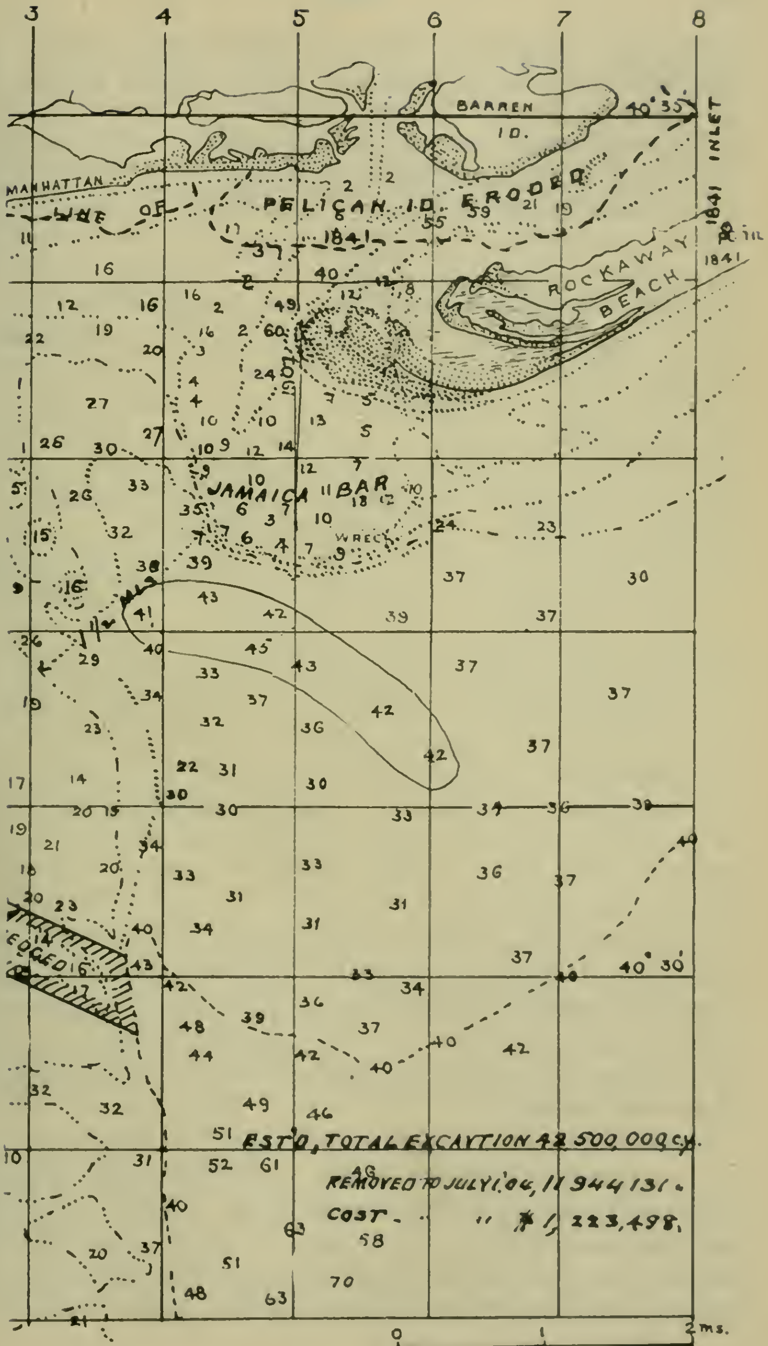
Co-ordinates.—As a basis of orientation the Sandy Hook Lighthouse is taken as the origin, since its co ordinates are practically identical on the British and American charts.

The axes of reference are the meridian of the lighthouse and the parallel of 40° 20′ 35″ N. latitude. On this meridian and parallel therewith, cross-sections have been constructed from the Coast Survey charts of 1841 and 1901, by dividing the arc of latitude into minutes (or 4,620 feet intervals) and taking the sectional area of the water extending for a distance of 3 knots southward. The area thus covered extended about 7·5 knots east and 3 south, embracing the traveling bank in front of Jamaica Bay and reaching beyond the old inlet of 1841.

The gain or loss in the water cross-sections indicates the amount of erosion or deposit in the past sixty years, but it should be noted that this is merely the local resultant change and that it by no means represents the total movement of drift. This latter quantity can best be ascertained only when it is finally impounded in the bight of some re-entrant, having no internal, tidal compartments. Along an open beach with numerous receptive inlets and a great bay at its terminus, all acting as pockets for sand, it is indeterminate, except by constructing an extensive groin to intercept it. Along an unbroken beach the volume of drift may be very large, yet the net changes, after its equilibrium is established, may be very small or zero. When a breach occurs, however, the sand enters and is precipitated on the inner bars and islands until the inlet drifts past and the bay or sound becomes closed to the littoral material, which then travels on to the next dump. The outer bar resulting from the effluent currents of the bay modifies to a great extent the action of the littoral forces by deflecting them in part around the submerged obstruction which they are constantly attacking on the windward side from which the sand is eroded and carried by a circuitous path to the leeward slope. At the toe of this latter slope and along the beach front beyond the bar there is apt to be erosion from the eddy caused by the returning currents. These generalities are illustrated by the following tabular exhibit computed from the cross-sections of the Coast Survey charts of 1841–1901, with such intermediate sections as were necessary to locate the scarps and counterscarps of the channel at these dates, or after sixty years interval. The sections are arranged from east to west to follow the direction of the movement. Between Nos. 7½ and 10, inclusive, there has been an increase of the water section or scour, but auxiliary sections extending farther east to Rockaway Life-saving Station show no material change, unless it be a deepening beyond the 5-fathom curve. Between the Jamaica and New York Bars there has been a small amount of scour in the flood-tide channel under Coney Island and a recession of the beaches which is pronounced along Plumb and Pelican Islands. A



NARROWS
3
2
1
0
1
2
L.H.
CONEY ISLAND
SHORE
LIGHT
AMBROSE CHANNEL
ROMER
FLYNN KNOLL
SANDY
HOOK


3
4
5
6
7
8
BARREN
ID.
40° 35'
INLET
MANHATTAN
LINE OF PELICAN ID. ERODED
1841
ROCKAWAY BEACH
1841
JAMAICA BAR
WRECK
EDGED
40° 30'
EST'D, TOTAL EXCAVTION 42 500,000 C.Y.
REMOVED TO JULY 1.'04, 11 944 131.
COST " $ 1, 223,498.
0
1
2 ms.

submerged ridge has formed in this trough which has reduced the depths from 28 to 15 feet—a loss of 13 feet.

COMPARATIVE MARINE CROSS-SECTIONS OF VICINITY OF JAMAICA INLET, EXTENDING FROM THE MERIDIAN OF SANDY HOOK LIGHT EASTWARD 46,200 FEET' 8·75 STATUTE MILES, AND SOUTHWARD FROM LATITUDE 40° 35' N. THREE KNOTS. FULL INTERVAL = 4,620 FEET.

No.	Date 1841 Sq. Ft.	Date 1901. Sq. Ft.	Decrease. Fill — Sq. Ft.	Increase. Scour +.	Volume. Cub. Yds. Deposited.	Remarks.
10	384,635	433,323	—	48,688	—	—
9	256,829	338,381	—	81,552	—	—
8	241,847	266,568	—	24,721	—	—
7½	172,842	253,177	—	80,335	—	Scarp of 1841
7	323,775	227,616	96,159	—	2,079,000	Through inlet and bar of 1841
6½	288,476	237,485	45,991	—	5,250,000	Counterscarp of 1841
6	293 345	216,661	76,684	—	6,160,000	=
5½	320,123	189,883	130,240	—	8,840,000	Scarp of 1901 { Deposited outside, 182,580 Scour inside 52,340
5	329,861	202,055	127,806	—	11,300,000	Gorge of 1901
4½	355,422	233,702	121 720	—	13,700,000	Counterscarp
4	322,581	402,893	80,312	—	5,555,000	—
3	323,775	283,607	40,168	—	10,000,000	—
2	206,924	224,919	—	27,995	2,000,000	—
1	158,236	186,231	—	27,995	—	—
0	121,937	139,978	—	18,041	—	On Sandy Hook Meridian
Av.	273,374	249,432	23,942		64,844,000	Deposited in 60 years ±

The difference of the mean sections gives an average reduction of 23,942 square feet, or about 900 cubic yards per lineal foot, which for the total distance of 46,200 feet would give 693,000 yards per year as compared with the nearly 1,100,000 as included in the bar reach and representing its annual increment.

The bar proper covers a length along the beach of about 3½ miles and extends seaward nearly the same distance, while the direction of its movement has changed since passing Rockaway Station from west to nearly southwest, and which, if continued, will pass through the Light on the Romer Shoal and bisect the Ambrose Channel. It is now but 2½ miles distant from the 6-foot contour of the Jamaica Bar to the 14-foot depth at the end of the new channel. There are no points between reaching to 40 feet excepting a small basin ½ mile wide, having one sounding as great as 46 feet, and as the Jamaica Bar rolls up on the outer slope of the main ridge with its diminishing depth the rate of progress will be more rapid and the distribution of material more extensive.

The table above shows the maximum reduction of the cross-section of the waterway at Station 5½ (the present scarp) to have been 130,240 square feet, which is greater than the entire area of the waterway for the 3 knots covered by the initial section at Station O, so that there is not space on the bar for this deposit without spreading to the southward and flowing into the channel just as the spit at Sandy Hook is now changing its direction and moving to the westward as the ramparts of the sea encroach upon the gateways of the tide.

Rate of Approach.—Under these conditions the question naturally arises as to how soon this great increase in the volume of material may be expected to reach the bar, and it is one more readily answered than that of quantity, since a comparison of the authentic Coast Survey charts from 1841 furnish evidence that the progression of the easterly spit of Jamaica Bay has been 2⅞ miles in sixty years or at the annual average of 253 feet, that is, 1 mile in 20·86 years. If the British chart of 1776, made by Sauthier, be taken as reliable the rate has been about 7 miles in 125 years, or 295 feet per annum. One mile in eighteen years, nearly.

As a further check under somewhat similar conditions of exposure and activity the charts for Fire Island show a westerly drift of 11,600 feet in 52 years, or 224 feet a year. The Board of Engineers of 1897, in reporting on the conditions at Aransas Pass, Tex., on the Gulf of Mexico, stated that "for many years it moved in a southerly direction. . . . The annual rate of movement from 1868 to 1878 was about 260 feet."

These few instances will serve to show that a movement of about 260 feet a year is not abnormal, and may be accepted as safe, so that the 40-foot basin should be crossed in about ten years, after which the rate should be more rapid in mounting the scarp of the outer bar. As it will require about ten years to remove the original material in place, in the Ambrose channel, which is already reported to have filled from 3 to 7 feet, where work has been done, it will be seen that the problem assumes a serious aspect, and there would seem to be no question as to the futility of attempting to create, and especially to maintain, a channel by "dredging on a bar exposed to the full force of the Atlantic," which the board of 1884 could not recommend for its permanent improvement.

But this is not all, for while the marine forces of the Long Island littoral are so rapidly storming the left flank of the enceinte, those of the New Jersey coast are likewise attempting to turn the right and rear. It is, therefore, necessary to reconnoitre in this direction to ascertain the force of the enemy and his line of approach.

Growth of Sandy Hook.—The encroachments of this peninsula of sand extending northwardly across the entrance for a distance of five miles, has long been a subject of investigation and a cause of alarm lest it ultimately close this portal to the harbor. The U. S. Coast Survey Commission made a special report on this subject in 1857, in which it said:

"The disastrous result of the continued growth of Sandy Hook into the main ship channel, its progress having been for the last century at the rate of nearly 'a sixteenth of a mile in twelve years,' needs no exaggeration to give it importance. . . . If its encroachments in the same direction were continued beyond certain limits, the destruction of the harbor might ensue.

"Within twenty years (1835–55) the point has grown to the northward 220 yards. It is altogether probable that the future progress of commerce will render the deepening of the bar a vital question."

The half-century just closed has fully confirmed these predictions, and lends weight to the need of a more extended analysis of the rate and direction of the drift which is gradually throttling this mouth of the bay.

The rates of growth above cited give an average of 26 feet per annum for the century, and 33 feet for the score of years, but the variations in the progress of the spit will be more clearly exhibited by the subjoined tabular statement, compiled from numerous charts, some of which are of doubtful authenticity, and hence of little weight.

As the opening and closing of the mouth of the Shrewsbury River at the root of the Hook is a factor in the travel of drift, an effort has been made to determine the dates when open.

An old provincial map of New Jersey, published by Seller and Fisher in 1676, shows a small projection of $\frac{1}{10}$ of an inch in length on the site of Sandy Hook, connected with the mainland; but as there is no scale, it is valueless.

A map of New York and Perth Amboy harbors in 1733, drawn to scale and apparently made from surveys, is taken amongst the earliest reliable maps for this study. On this chart the Hook is but three miles long, which is apparently erroneous as compared with Lay's map of 1724. The depths of 19 fathoms in the narrows and 3½ in the main ship and Gedney's channels are the same as those prior to the dredging, commenced under the project of 1884.

A glance at the rate-column shows some very eccentric features and impresses the need of systematic records at stated periods as a basis for definite conclusions. It would appear that, for the half-century from 1724 to 1776, the spit was in a condition of equilibrium (neglecting the survey of 1733). During Lord Howe's occupation a spit of sand nearly half a mile in length extended to the northwest, and the fast land soon followed it. Another cycle occurred between 1779 and 1848, a period of sixty-nine years, during which ·43 of a mile, or 2,288 feet, were reclaimed from the sea, giving an average progression of 33 feet per annum. Since 1848, whilst there has been fluctuation, there is no material advance upon the channel northwardly, but instead there has been a protrusion of a long spit of a half mile to the westward, forming the third cove on the inner face of the Hook.

MOVEMENTS OF SANDY HOOK AND CONDITION OF SHREWSBURY INLET.

Date—Year.	Lengths—Miles.	Feet.	Authority.	Inlet Closed or Open.	Average Rate Per Annum In Feet.	Remarks.
1724	4·00	21,120	Amos Lay	Closed	For 50 years to 1776 there seems to have been no advance	Scale $7^{m} = 1''$
1733	3·00*	15,840	Not stated	"		" $3\frac{1}{3}^{m} = 1'$
1769	3·96	20,909	Lt. Ratzer	"		" $6\frac{2}{3} = 1$
1776	4·00	21,120	(Hudson River)	"		" $4^{m} = 1''$
1778	4·40	23,232	"Lord Howe"	Open	1,056	" $\frac{3}{4} = 1''$
1779	4·4	23,232	C. J. Sauthier	"	0	" $5 = 1''$
1782	4·5	23,760	Lt. J. Hills	"	176	" $\frac{1}{10000}$
1819	4·53	23,918	Capt. LeConte	Closed	4	" "
1836	4·67	24,657	U. S. C. Survey	Opened in 1835	43	" "
1841	—	—	"	"	—	" "
1842	4·80	25,344	"	Closed	114	" "
1844	4·83	25,520	"	—	88	" "
1848	4·83	25,520	"	Open	0	" "
1850	4·80	25,344	"	Closed	— 88	" "
1851	4·78	25,388	"	Open	+ 44	" "
1855	4·77	25,335	"	Closed	— 13	" "
1857	5·00	26,400	"	" †	+ 530	† Permanently by railroad
1863	—	—	—	"	—	Severe storm cut away, making jetties and rip-rap necessary, 2,575 feet long.
1881	4·9	25,872	—	"	— 26	
1891	4·8	25,344	U. S. C. Survey	Closed	— 75	Scale $\frac{1}{10000}$

* Distance uncertain. † Six feet deep.

The revetment of the head of the Hook after the severe storm of 1863 checked the erosion to some extent.

In 1881 the nucleus of the westward movement was shown to have commenced. Taking the depth at 45 feet with slopes of 1 on 12, this deposit to date would represent approximately 10,000,000 cubic yards, or about a half-million a year, which has been arrested under the lee of the Hook, notwithstanding the inner littoral current which prevails for eleven hours out of the twelve. This does not represent, by any means, the additional amount of sediment carried into the bay in suspension and deposited in its channels and on its bars. The annual dredging required to maintain the full dimensions of Gedney's Channel, especially on the south side of the cut, indicates the presence and source of this material.

This may be checked by the larger deposit made on the Hook proper between 1776 and 1857, when it advanced nearly a mile in length and expanded to a mean width of a mile. The uncertain element in this computation is the mean depth of the bed, but as there is always a deep water, reaction basin at the head of such spurs reaching to between 50 and 60 feet, it is safe to assume the depth of the fill at 15 yards. With these dimensions the yearly deposit has been 581,000 cubic yards on the fast land of the Hook, thus confirming within reasonable limits the probable annual deposit in this vicinity to be in round numbers 500,000 cubic yards. The northern mile of the Hook contains about 46,500,000 yards in place.

Unfortunately, the data contained in the above table furnish an uncertain basis from which to determine the age of Sandy Hook, but between the surveys of 1776 and 1857, a period of eighty-one years, it apparently advanced 1 mile, or at the rate of about 65 feet per annum. To cover the entire 5 miles, at this rate, would require about four centuries, leading back to the date of the discovery of America. It is highly probable that the rate was much less at an earlier date, when the coast to the southward was indented with numerous inlets which have nearly all been closed by the northward littoral drift and converted into fresh-water lakes. The only important openings to-day are those of Shark River and Manasquan, until Barnegat is reached, where the drift is to the southward.

From the foregoing statements it would appear that both flanks of the entrance are menaced by large deposits of sand in place, whilst the flood tide is augmenting this volume by material carried in suspension, thus hastening the deterioration of this entrance by these encroaching banks.

THE GREYTOWN HARBOR.

That this is no idle fancy will appear from a brief consideration of the physical conditions at the mouth of the San Juan del Norte, at Greytown, Nicaragua, upon which so much stress has been laid in recent years. Here the trade-wind, rather than the tide, is the predominating element, to drive the waves to the westward and extend the hook in that direction, so that the excellent roadstead which existed in 1832 was completely sealed in 1865, during which period of thirty-two years the spit had advanced over a mile and a half, moving at an average rate of 291 feet, each year.

A careful computation from comparative cross sections of this cordon of sand, covering a period of some forty years, made by the writer on the spot in December, 1897, gave the annual deposit as 582,000 cubic yards during the latter part of the movement.

By a comparison of the survey of Commander Lull, of 1872, with that of Captain West, of 1865, covering a little more than seven years, after the lagoon had been formed, Prof. Henry Mitchell estimated the average yearly deposit on the sea slope of Punta Arenas to be 730,000 cubic yards. Here the coastal plain is characterized by five distinct lagoons—Ibo, Barco, Sucio, Shepherd's and Greytown—having their axes nearly parallel and from 3,000 to 3,750 feet apart, all to leeward of the salient and within 3 miles of the coast, thus demonstrating the persistence of the forces and their cyclic results. The short pier of 1,000 feet, built by the Maritime Canal Company, arrested this drift and caused a general advance of the shore line to windward for a distance of more than a mile. It also opened and maintained a channel into the lagoon until the groin filled up.

This typical instance is cited to illustrate the gravity of the encroachments upon the New York bar where the aggregate deposits are more than twice as great, being concentrated from both the Long Island and New Jersey coasts, as from a funnel, upon the bar stretching from Coney Island to Sandy Hook.

Land Titles.—Aside from the physical, engineering or commercial importance of this question there is the legal one of proprietorship. Stakes, pins or landmarks driven into these traveling beaches do not hold them down and the inaccuracies of the early colonial surveys and descriptions are so vague as to lead to great confusion. In a

Supreme Court decision rendered in July last in favor of the town of Hempstead, Long Island, the defendant, based upon surveys several centuries old, the Court ruled "That old maps of the beach on Long Island are but slight evidence of the condition of the beach or the location of the inlets at a period fifty years earlier, even though correct at the time made. It is a fair presumption that the constant shifting in the various inlets of Rockaway Beach on Long Island, shown to be going on at the present time, was going on in 1725." From this it appears that such a description as is contained in the deed of "A beach lying on the south side of the Island at a place called Rockaway," is not such as would convey title to a definite tract of land, subject to the action of such physical forces.

For the purpose of preserving to the rightful owner the full possession of his property, therefore, it becomes of importance to establish well-defined reference marks and to ascertain by frequent and systematic examinations the character and amount of the changes which are taking place as a basis for the best method of reclamation and protection to riparian owners with correlative aid to commerce and marine industries.

The Remedy.—In view of the situation the preventive measures seem to be self-evident, yet thus far no permanent regulating works are contemplated which look to the modification of the tidal forces, either to diminish the rate of encroachments from the flood-driven sand bars or to augment or localize the energy of the ebb scour, so that it is risking nothing to say that the Board of 1884 was correct in its judgment as to the inexpediency of attempting to meet the demands of commerce by dredging. If it were true then, it is more so now, and yet it is quite possible so to control the ebb currents by a permanent training wall as to cause them to cut out and maintain by their own energy an ample channel across this bar. Such a structure would not obstruct nor close any of the existing channels, but would protect the Ambrose Channel from drift and would cost only about one-half the amount estimated for merely the preliminary dredging of the proposed channel. This should be supplemented by auxiliary works to impound the traveling sands in natural depositories, where they will become valuable instead of injurious, and prevent the ultimate formation of a new beach in front of Manhattan and Coney Island, which will ultimately be on a bay a mile or more from the sea.

The details as to plans, dimensions, mode of construction, materials and cost of these works, belonging more properly to the subject of the Engineering Section, are consequently omitted from this paper, which is respectfully submitted for discussion, though with a consciousness of the deficiency and unreliability of the earlier data.

CLOSE OF THE ST. LOUIS FAIR.

The Exposition at St. Louis, which was opened to the public with an attendance for the first day of about 180,000, was brought to a close on December 1st, with a record of over 200,000 admissions. The closing day was marked by ceremonies expressive of the debt which the Exposition owes to the executive ability and enthusiasm of its president, the final addresses being delivered in the Plaza St. Louis, and at the foot of the Louisiana Purchase Monument, where seven months ago the Exposition was formally declared to be opened. The Exposition buildings were closed at four o'clock in the afternoon, and at midnight the splendid illuminations of Festival Hall and the Cascades slowly faded out for the last time, leaving this, the largest, most ambitious of the great international expositions, a matter of history.

Interest naturally centers at this time in the finances of this great undertaking, and according to a statement of the secretary of the project, since its inception, has cost about $22,000,000 to the Exposition Company, while the several States and Territories have expended a total of $9,000,000. There were 18,500,000 admissions, and the receipts reached a total of about $10,000,000, which is made up of admissions and concession royalties. It was announced that when a few current accounts have been paid, most of the $1,000,000 in hand will have been consumed, leaving only a small amount for the stockholders. From the amount of royalties collected, it is estimated that the various concessionaires must have taken in at least $10,000,000. The entire cost of the whole fair, including the various concessions, is estimated at about $50,000,000. With the bringing to a close of one more of these colossal expositions, the question will be asked again as to whether they pay. From the figures given above it is evident that financially they do not; but everyone who has visited this fair and taken note of the character and behavior of the multitudes that streamed through the various Exposition palaces, will surely give it as his impartial conclusion that as a great educative force, whose influence is much wider than can be measured in turnstile statistics, the last of the world's fairs must, in a broad sense, have been a profitable undertaking.—*Scientific American.*

Mining and Metallurgical Section.

Stated Meeting, held Thursday, December 22, 1904.

Fundamental Principles Involved in Blast-Furnace Practice.

By Edward A. Uehling, M.E., New York.
Consulting Engineer and Member of the Institute.

To produce with the greatest possible regularity and fuel economy, the maximum per cent. of the quality of iron desired, and the maximum output of which the design of the furnace and its mechanical equipment will permit, none of the recognized essentials must be overlooked, and many things observed and attended to, that have not received the consideration which their importance merits.

RAW MATERIAL.

The Ore should be of uniform quality, or a uniform mixture of ores of dissimilar qualities, chemically adapted, to yield collectively the iron desired, and to produce with the flux available that quantity and composition of slag best adapted to fulfil its proper functions in the process of smelting. Neither a very lean ore, or ore mixture, nor yet ores that are exceedingly rich in iron, are conducive to obtaining the best results, but a regular mixture of low grade ores will yield better results than an irregular mixture of much higher average grade, certainly as to quality and generally also as to quantity of output. In regard to a few of the chemical elements the ore must be, and always is, selected and mixed to produce the desired iron; but in regard to the physical condition there is at best but a limited choice and frequently none whatever. It may be laid down as an axiom, that the more refractory an ore is the finer it should be physically to become readily reduced. In the storeroom of nature we find, however, that the more refractory ores occur generally in compact masses, while those easily reducible are most frequently found in a more or less finely comminuted state.

The logical corollary to the above axiom, viz., that the finer the comminution of an ore the greater its reducibility, and hence the more readily it can be smelted, while theoretically correct, does not hold good in the blast furnace, and especially not in the modern blast furnace. Two reasons why this should be so present themselves very readily; first, the finer the ore the greater must be the resistance offered to the ascending gases, and, second, the greater must also be the quantity of ore dust carried over into the gas flues. These difficulties give rise to others which with certain ores have frequently proven serious.

In smelting very fine ores the increased blast pressure was the objection that made itself felt first, and in the measure as this was being overcome by stronger blowing engines, the loss in flue dust was increased. No serious difficulties were encountered, however, until after the advent of the ores from the Mesabi range. These ores, while unsurpassed in chemical composition, ease of reduction, and cheapness of getting, possess physical properties which illy adapt them for conversion into pig iron in the monstrous blast furnaces in which they are being smelted. In the majority of the deposits the very fine ore preponderates, in some cases as high as 20 per cent. will pass through an 80-mesh sieve. Much of this very fine ore is carried over with the gases. The average loss of Mesabi ore in flue dust is between 3 and 5 per cent., and greater loss is not uncommon.

PREPARATION OF ORES.

Crushing.—Although much advance has been made in the past decade in the way of preparing the harder varieties of ore by crushing them, generally at the mines, which is the proper place, instead of depending on a few men in the stock-house to break up the largest lumps with sledge hammers; yet, little or no attention has been given to the actual requirements. All hard ores are crushed to a given size, irrespective of their reducibility. Hematite ores generally go into the furnace in a finer state of comminution than magnetites, when because of their great reducibility the reverse should be the case. It is the author's opinion that all hard ores could bear much finer crushing than is at present customary, and that this would be conducive to fuel economy particularly with the magnetites. The latter could be crushed with advantage so as to pass through a 2-inch round-holed screen, and even smaller.

Sizing.—The importance of sizing or separating ores with regard to their relative coarseness or fineness has as yet received but little attention in American blast-furnace practice. I dare say the majority of furnace managers have not given this phase of the subject the thought and careful study it deserves.

Every furnace man objects to either very fine or very coarse ores, and all would, no doubt, prefer a uniform and relatively coarse ore, but since it is quite the exception that uniformly coarse ores can be supplied, they must be taken as they come, and the general practice is to charge the coarse and fine ores indiscriminately as they happen to be at hand, or at best attempt to mix them as much as possible. The former method is bound to produce more or less serious disturbance in the working of the furnace; not only because of the physical irregularity, but also because the fines of a given ore may vary very considerably in composition from the coarser portions. The uniform mixing of the coarse and fine ores, though much better chemically, at least, is, nevertheless, far from being the best method of charging.

The worst possible ore mixture, from a physical point of view, is that in which the coarse and fine are so proportioned and so thoroughly mixed that the latter fills all the interstices between the lumps of the former. A layer of such a mixture is less penetrable, offers greater resistance to the ascending gases, hence requires a higher blast pressure and is apt to produce more flue dust, and is therefore less desirable than if it consisted of fine ore alone. This is true to a greater or lesser extent of all mixtures of irregular sizes, and the greater the difference between the coarse and the fine, the worse. To be right, ores should be separated into three, or preferably into four sizes, viz.: coarse, medium, fine, and dust. All ore passing over, say, 1½-inch mesh screen to be classed as coarse; through 1½-inch and over ½-inch to be classed as medium; through ½-inch and over $\frac{1}{20}$-inch mesh to be classed as fine, and all that passes through $\frac{1}{20}$-inch mesh to be classed as dust. The latter should either be briquetted or agglutinated in some satisfactory manner or else smelted in a furnace by itself, designed and equipped for the purpose, preferably in a low, wide furnace, blown with a mild blast through tuyeres of variable penetration, or perhaps electrically. The coarse, medium and fine ores could be smelted together in the same furnace with a strong blast. To do so to the best advantage they should be charged in separate strata. The above scheme, *i. e.*, to first separate the ore into several sizes and then fill them separately, will, no doubt, be objected to as impracticable, as an expensive and useless complication, or at best a refinement of doubtful utility. Whether such objections are all, or only partly, or not at all true, depends on our viewpoint. If we should attempt it with the present equipments, even the most modern, it would probably be impracticable; if we feel that we have reached the acme of perfection in blast-furnace practice, it must seem a useless complication, and if the present output is qualitatively as well as quantitatively fully satisfactory, the sizing of the ores would certainly be of doubtful utility. If, however, we wish to combine uniform quality with maximum output and greatest fuel economy, we must seek to eliminate all disturbing factors, and the physical irregularity of the raw material certainly is one of them.

Roasting the ores is resorted to generally only for the purpose of eliminating such deleterious constituents from the ore as can be driven off by heat. The process is always carried on in an oxidizing atmosphere. In this country the roasting of ores is rarely resorted to, except for the purpose of eliminating sulphur. All magnetic ores are improved by roasting, and the question whether it would pay or not to do so depends entirely on local conditions; first, on the cost of coke or other furnace fuel, and, second, on the market value of electric current. The same is true with other varieties of ores; for example, the hard red ores of the Birmingham district, which could be greatly improved by roasting. Time and space do not permit going further into this subject at this time.

Briquetting, Agglutinizing, Cindering, Electric and Chemical Treatment—all these relate to putting ore dust into some form that will overcome its objectionable qualities. Much time, ingenuity and money have been expended in this direction, resulting mostly in failure or at best in indifferent success. This, however, does not imply that the problem cannot be solved, or even that it may not have been solved already by some method awaiting practical demonstration and commercial development. Much could be said about promising methods, if time permitted.

As stated above, theoretically, the finer the ore, the more economically it should be smelted. To the practical objections already mentioned which manifest themselves against the use of very fine ores, viz., heavy blast pressures and reduced yield, etc., should be added the difficulty encountered in properly distributing the fine ores over the coke charge. The latter problem fully solved, the author is of the opinion that the very fine ores could be smelted to best advantage by themselves in a specially designed blast furnace. Smelting in an electrical furnace possesses possibilities of success which depend chiefly on the cost of power, and with the proper utilization of the blast-furnace gas its practicability as an adjunct to the blast furnace becomes very much less doubtful, and may prove profitable under certain local conditions.

Flux.—Under the general term of flux, we understand that addition to the material smelted, which will chemically combine with the gang and other impurities of both ore and fuel and produce a liquid slag. It so happens that with very few exceptions the acid elements contained in the gang largely predominate. For this reason, the flux must nearly always be basic, and because of its abundance and cheapness, limestone is almost invariably used. Should, however, the basic element in the ores predominate, an acid flux would have to be added, and quartz rock or highly silicious iron ore take the place of limestone.

Preparation of Flux.—What has been said of the preparation of ores holds good in a general way also for the preparation of the flux. It should be well broken, and as much as possible of uniform size; dust should be entirely avoided. Theoretically, it would be of considerable advantage to calcine the limestone or dolomite before filling into the furnace. There are, however, practical difficulties due to the fact that unless the stone is very hard burned, it readily becomes air-slaked, and is then worthless, since it is too largely carried over by the blast. Attempts that have been made to drive off the carbonic acid before filling into the furnace have generally failed on that account.

Slag.—The function of the flux, as we have seen, is to fuse with earthly impurities of the ores and fuel and melt into a liquid slag. The function of the slag is two-fold—physical and chemical. Physically it acts first as a filter, purifying the globules of reduced iron as they pass through, and, second, as a blanket protecting the metal against possible oxidation by the blast. Chemically its most important functions are to absorb and carry off sulphur, and to assist in regulating the silicon content in the iron.

Magnesia is a stronger flux than lime in ratio of their respective atomic weights, and with an ore mixture comparatively free from sulphur smelted with a low sulphur fuel, dolomite is proportionately more efficient than carbonate of lime; but since sulphur exists in the slag only in combination with calcium, the latter element must predominate where considerable quantities of sulphur are to be removed.

The proper composition of the slag is of greatest importance, and in selecting ores, and also the fuel, due consideration should be given to the composition of the gang and ash respectively. Alumina should be kept as low as possible. Although this element does not materially reduce the fusibility, it does largely reduce the fluidity of the slag, and fluidity is of the most vital importance in a blast-furnace slag. So far as the author's experience goes, the lower the alumina can be kept the better; and if a slag results from the regular mixture containing over 15 per cent. of alumina, silicon material should be added to the burden. A slag to be most efficient should melt like ice, and not like taffy: that is to say, it should retain a solid form until it melts, and as soon as melted it should be quite liquid, instead of gradually passing from the solid to the liquid state. The latter property causes sticking and hanging, and on account of the sluggishness of such a slag, it cannot fulfil its functions properly. It has a tendency to retain the finer globules of iron, thus causing material loss.

Generally the ores contain ample earthy impurities so that with the addition of flux necessary to form a desirable slag, the proper quantity is also produced. In many instances it has proved to be good practice to add silicious material for the purpose of improving the quality of the slag as well as of increasing the quantity.

Fuel.—The fuel for the blast furnace may be raw coal, charcoal, anthracite, or coke. The first of these has entirely ceased to be a factor in the production of pig iron in this country. The percentage of charcoal used is becoming less and less as timber becomes scarcer and dearer. The same holds true for anthracite coal, because of its limited supply, and although still used in considerable quantities it is bound to be practically replaced by coke in the not distant future. Coke, besides its practically unlimited supply, possesses all the essential qualities of a superior blast-furnace fuel.

The fuel performs two functions in the blast furnace—physical and chemical. The physical function of the fuel consists in preserving a comparatively open stratification in the descending column of stock in the furnace, thereby permitting an easy upward flow of the ascending gases. To fulfil this function properly the fuel should be coarse and rough, and as uniform as possible in size. Very large lumps are as undesirable as fines. It should be of sufficient strength to reach the tuyeres with the least loss by abrasion. Fuel dust, or breeze, should never be charged into a blast furnace; the most of it is directly blown over with the gas, and what little is retained in the furnace is apt to do more harm than good.

The chemical functions of a blast furnace fuel are twofold. (1) To generate by semi-combustion with the oxygen of the blast, all the heat necessary for the process of smelting, and (2) to produce the reducing gas necessary to convert the ore to the metallic state. It should possess the greatest possible cell development consistent with the required physical strength, so as to offer the maximum surface to the oxygen of the blast, and yet possess such chemical stability that it is but slightly affected by the oxidizing action of the CO_2 in the upper zones of the furnace. To possess these properties the first requisite is that the coke is well burned and made from coal which will produce the proper cell structure and necessary strength.

The most objectionable element contained in coke is sulphur. Phosphorus is of importance only when special irons are being manufactured. The composition of the ash is of as much importance as the quantity. The alumina should be as low and the silicon as high as possible. This holds true especially where foundry iron is smelted. Iron is a valuable constituent, and is often contained in sufficient quantity to add appreciably to the yield of the ore. The author is of the belief that most of the silicon in the iron produced comes from the ash of the coke; and if the ash, therefore, is of the proper composition it may add materially to the ease of producing high silicon iron.

Air.—The largest, the cheapest, and the most neglected constituent of the raw materials involved in the process of smelting is the air which furnishes the oxygen required to burn the fuel and produce the heat and chemical reactions.

Strictly speaking, the blast is furnished to every furnace variable in quantity, irregular in temperature, and, worst of all, variably contaminated by moisture, and because of these, as much as other irregularities, also at variable pressures.

Regularity of Blast.—First regular quantity. It is probably quite within the memory of most of the older furnace men, if not within their own experience, that it was the general practice to regulate the blast by pressure. In England, where they still generally blow several furnaces (as many as six or more) off the same blast main, this practice of necessity prevails. In this country blowing by volume is the rule. The blowing engines are ordered to be run steadily at the required revolutions; but variable steam pressure is a disturbing factor, variable blast pressure is another. Then again constant revolutions, *i. e.*, constant volume by engine measurement does not insure a constant quantity of blast delivered into the furnace. Innumerable, avoidable and unavoidable leaks, between piston and tuyeres, engine-room temperature, and the barometric pressure of the atmosphere, affect the quantity delivered. The latter alone may affect the quantity delivered from 6 to 10 per cent., and loss through leakage from 10 to 15 per cent. and more is not uncommon.

The author believes himself to have been among the first to blow a furnace by constant volume. The change from pressure to volume blowing at once brought a noticeable improvement in the regularity of the output, but the number of charges taken by the furnace did not agree as closely as they should with the regular quantity of wind supposed to be delivered by the blowing engines. Revolution counters were attached to the engines, and the fact was at once revealed that the revolutions marked had not been regularly blown. Getting the engineers interested resulted in a friendly rivalry to blow the exact number of revolutions. For longer or shorter intervals the fuel charges would agree with the revolutions, then again there would be puzzling discrepancies that could not be explained by irregularities in the working of the furnace. Barometer and thermometer observations finally practically cleared away all otherwise unaccountable discrepancies, except that the calculation showed the quantity of air delivered by the blowing engine to be far in excess of that required to burn the fuel consumed. The numerous small leaks, which had not been considered of much importance prior to accurate determination of wind and fuel relation, were stopped, and a gain of 5 tons per day was the result.

These few digressive remarks are recited here merely to show the importance of small things. There is so much in the phenomena of smelting in a blast-furnace which cannot be directly observed, that it behooves every furnace manager who wishes to keep intelligent control over his charge to pay attention to all the influencing factors. The barometer and the wet and dry bulb thermometer have received practically no attention. Revolution-counters are not as generally adopted as they should be. Autographic recording instruments should be used wherever available. The fact that the cost of air does not directly enter into the cost sheet is no reason why it should not receive proper attention.

Regular Temperature.—Neilson's invention of the hot-blast stove was, no doubt, the greatest single step taken in advance in the process of smelting iron in the blast furnace. Every 100° of heat added to the temperature of the blast is equivalent to 3 per cent. of the carbon burned at the tuyeres.

To what degree it is practical and economical to carry the heat of the blast is still an undetermined question. Practical furnace men differ much in their opinion. Sir Lothian Bell came to the conclusion, derived from his famous investigation of the chemical phenomena of the blast furnace, that not much could be gained after reaching 1,000°; nevertheless, they are to-day carrying at his own furnaces as regularly as possible from 1,400° to 1,500° at the Clarence Works, Middlesbrough, England. In Germany 1,500° to 1,600° of blast temperature are not uncommon. In this country the average blast temperature does probably not very much exceed 1,000°. Some furnace managers would like to carry higher temperatures if they could get them; others contend that high blast temperatures invariably lead to trouble. Theoretically, the limit of blast temperature is not reached until the fuel displaced by the heat of the blast has reduced the quantity to such an extent that the CO formed is insufficient in quantity to reduce the ores carried. The blast furnace cannot be successfully worked on heat alone. A sufficient quantity of reducing agent must be supplied as well, and there must be enough solid fuel to fulfil its physical function. While there is, therefore, ample room for difference of opinion as to what is the most economical temperature, there exists no such difference of opinion as to the desirability of a controllable regular temperature.

The introduction of the regenerative hot-blast stove was a great improvement over the iron-pipe stove in so far as enabling higher temperatures to be obtained; at the same time, it brought with it the very detrimental factor of variability of temperature. The loss of temperature in an hour's blowing, which is the almost universally adopted period, is rarely less than 200° and not infrequently reaches 300° and more. Since 100° blast temperature are equal to 3 per cent. of the fuel burned at the tuyeres, we see that these variations amount to from 6 to 10 per cent. of fuel in the hearth. That this variable factor must necessarily produce detrimental variations in the vital part of the furnace is evident. How this variation can best be avoided or overcome the author has attempted to show in an article published in the *Iron Age*, May 19th last.

With thoroughly purified gases the hot-blast stoves can readily be so constructed that they will yield a blast of very high and practically uniform temperature, which can then be readily tempered down to any degree necessary or desirable. So long, however, as iron masters will persist in using dirty gases, there is little chance of improving the hot-blast stove. The only thing to do is to make them bigger and build more of them. Why furnace proprietors should persist on these illogical and costly lines is difficult to understand. The money put into new and enlarged hot-blast stoves would nearly, if not quite, pay for an installation of gas-washing plant, which would produce much more economical and satisfactory results; as the author has shown in the paper referred to above, that the blast can be readily kept at a uniform temperature by the introduction of cold blast. To do this, however, it is absolutely necessary to know the blast temperature, and it is strange to say that with a few laudable exceptions, blast-furnace managers east of the Allegheny Mountains have not availed themselves of the proper means to do this.

To have control of the heat, it is not sufficient to test the temperature once an hour, but you must be able to see what the temperature is at any moment, and what is even more important is to have an instrument which is absolutely beyond the control of the man responsible for the temperature. An autographic record is of the greatest value. Without a positive knowledge of the temperature carried at all times, intelligent heat regulation is impossible and perfect control out of the question.

Composition of Blast.—There are few, if any, furnace managers that are not aware of the fact that humidity is an important element in the blast. Very few, however, have taken the pains and the trouble to determine what this factor amounts to quantitatively. During the period referred to above, the author made hygrometric determinations and was surprised to find that the quantity of water carried into the furnace by the blast during the humid summer months amounted to tons of water in twenty-four hours. It is not uncommon for the air to contain 8 grains of moisture per cubic foot. At this degree of humidity a blast furnace taking 35,000 cubic feet of air a minute will, therefore, receive

$$35{,}000 \times 8 \div 7{,}000 = 40 \text{ pounds of water vapor per minute,}$$

or 2,400 pounds per hour, or over 28 net tons in twenty-four hours. Since that time (1886) the author has persistently advocated the economical importance of removing this moisture from the blast, and the process of refrigeration as the best method for removing it.

Knowing the amount of moisture going into the furnace with the blast, it is easy to figure the fuel required to neutralize its chilling effect. Making this calculation we find that one pound of moisture requires in round numbers 1·3 pounds of carbon to be burned at the tuyeres to replace the heat absorbed by the decomposition of the water vapor. This, in itself, amounts to a very considerable quantity of fuel during the summer months, yet it is less than 25 per cent. of the actual fuel saved, as demonstrated at the Isabella Furnaces by Mr. Gayley's desiccating plant.

The strictest attention is paid by every furnace manager to guard against water getting into the furnace through leaky tuyeres or cooling plates, yet absolutely no regard is given to the contamination of the blast by avoidable moisture. Innumerable steam leaks are often allowed to exist in the engine-room, nearly all of the steam from which is carried into the furnace without any idea of the fuel necessary to overcome this extra moisture. So long as these leaks do not become positively annoying to the engineer, they are rarely attended to. One instance in the writer's experience may be permissible to illustrate. At the plant in mind the blowing engines and pumps were in charge of the master mechanic of the works, over which the furnace manager had no authority. Repeated requests to repair the leaky joints were ignored. Hygrometric tests of the blast showed that it contained between 5 to 7 grains of moisture per cubic foot above the outside atmosphere. Calculations based on this moisture content laid before the general manager brought the necessary pressure upon the master mechanic. The steam pipes were overhauled. The effect was an immediate reduction in the fuel consumption of 150 to 200 pounds per ton of iron. There is no doubt in the author's mind that similar fuel economies might be obtained at many of the existing plants.

In the author's estimation desiccation of the blast is a step in advance, second in importance only to the hot blast, and that it will be as generally and perhaps even more promptly adopted.

Chemical Reactions.—Practical furnace men are, as a rule, very much in the dark as to the chemical reactions which take place inside of the blast furnace. Accurate data, both as to the temperatures existing and changes which take place in the various zones of the modern blast furnace, are entirely wanting. Such an investigation as was carried out by Sir Lothian Bell nearly forty years ago is very badly needed to throw light on what actually takes place in a blast furnace under the so materially changed conditions and methods of modern practice.

Every blast-furnace manager knows, of course, the nature and composition of the raw material charge at the top, and the physical condition and chemical composition of product tapped out at the bottom, and can and should know the composition of the escaping gases. And all this indicates to him more or less clearly what is actually going on inside of the furnace. But in reality all he knows with certainty is the beginning and the end. We know that all the carbon that reaches the tuyeres is burned to CO, and that this reaction is the principal source of heat by which the process of smelting is carried on, and that the CO is the all-important reducing agent.

From the composition and temperature of the escaping gases we can make inference as to the relative efficiency of the furnace at the time. From the appearance and chemical composition of slag and iron we can tell whether the furnace is in good or bad working condition, but of the actual chemical reactions taking place in the interior of the furnace, either as to their sequence or relative importance, we know practically nothing.

Carbon Impregnation is one of the important phenomena about which we are still very much in the dark. It had been observed before, but was first prominently brought before the iron metallurgists through the researches of Sir Lothian Bell, that sesqui oxide of iron (Fe_2O_3) possessed the property of splitting up CO into $C + CO_2$ at temperatures existing in the upper region of a blast furnace. This phenomenon has recently been the subject of scientific investigation and is very ably discussed in *Stahl und Eisen*, No. 21, 1904, by Dr. Aloys Weiskopf.

All hematite ores possess this quality to a greater or lesser degree and some of these from the Mesabi range are most remarkable for their capacity to become impregnated with carbon.

Experiments conducted by Mr. O. O. Landig* showed that the ore of some of the deposits became impregnated to such an extent that their volume was very considerably increased. This being so, it is more than probable that most of the difficulties experienced in smelting the Mesabi ore are due to this quality of excessive carbon impregnation.

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* *Transactions of American Institute Mining Engineers*, Vol. XXVI. "Action of Blast Furnace Gas on Various Iron Ores."

Hanging of the Stock in the upper part of the furnace is, no doubt, entirely due to this phenomena, for it necessarily follows that the swelling of the ore must increase the resistance to the gas currents and must also increase the friction against the inwall of the furnace. Now if we consider that even under the most favorable conditions, by far the greater part of the column of stock is supported by the normal friction against the inwall, and the further fact that 1 pound of unbalanced gas pressure will sustain approximately 1 foot in height of the column of stock, it is not difficult to understand how the downward movement of the solid material may be arrested without involving any other factor than excessive carbon impregnation.

A portion of the stock column having once come to rest, it is bound to remain at rest until the cause of arrest is removed. This necessarily follows from the fact that friction of rest is greater than friction of motion, so that if there is sufficient friction and pressure developed to cause a moving body to come to rest, there is always more than necessary to hold it stationary. Meanwhile, the consumption of fuel continues at the tuyeres in accordance with the volume of oxygen forced in by the blast. The iron sponge is carburized and melted, the dross of both ore and fuel combines with the flux and is fused into a liquid slag which descends with the iron into the hearth, where they take up very little space compared with their original bulk, and from which they are tapped off from time to time. As this process of smelting goes on, that portion of the column of solid material which is free to move in the furnace shaft above continues to descend. This causes a break between the arrested and moving part of the stock column. A cavity is soon formed which continues to increase in dimension in proportion as the moving column is smelted and consumed. The shorter this column gets, the less is the resistance it offers to the ascending gases, hence, with a given blast pressure, the pressure in the cavity must also increase, thus giving the stationary column still greater support.

Slipping.—On the other hand, it is evident that since no cold stock enters the furnace during the period of hanging, its contents must become hotter and hotter; also that the increased temperature will accelerate chemical reaction. Reduction progresses more rapidly; the carbon deposited at the lower temperature is consumed by the oxygen, liberated from the ore which it had impregnated, or by reducing CO_2 to CO, probably both. As this process proceeds, the stationary column necessarily shrinks, gradually loses its hold on the wall, and finally breaks away. This phenomenon is called a slip or slipping.

There are two distinct varieties of this phenomenon, the one due to causes just discussed known as top slips, always occurring in the upper half of the stock column; and the other, called bottom slips, to which I shall recur later, due to causes entirely different and always occurring in the lower part of the furnace, generally within the limits of the hearth and bosh.

To have a furnace slipping is always unpleasant. It is frequently serious and on several occasions resulted very disastrously.*

Prior to the introduction of the Mesabi ores, top slips were of very rare occurrence, and when they did occur were of a comparatively mild form, but no sooner had these ores become an appreciable part of the ore mixture than these phenomena of slipping became more and more frequent and very often manifested themselves with such force that "explosion" seemed to be a more appropriate term than "slip," and hence the phenomena is generally referred to as "Mesabi ore explosions."

When we consider that the dislocation of the charging hopper and top plates was an every-day occurrence and that on several occasions the whole charging apparatus, weighing many tons, was blown clean off the furnace and large quantities of stock were scattered broadcast, it appears quite natural that the explosion hypotheses should have seemed necessary to explain the effect produced.

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* It will be remembered that Captain Jones lost his life by being enveloped in white hot coke, slag and molten iron, bursting forth from one of the Edgar Thompson Furnaces in consequence of a bottom slip, and that Ed. Reisse was burned to death by the hot stock thrown from a furnace in his charge at New Castle, Pa., due to a top slip.

On the other hand, a little calculation will show that the force necessary to throw a bell and hopper out of a furnace is not so great as would appear from the mere statement of the fact that they weigh many tons. A gas pressure of 1 pound per square inch, when applied to a circular area 12 feet in diameter, exerts a lifting force of considerably over 8 net tons, and on an area of 14 feet in diameter of fully 11 net tons. This is quite sufficient to lift the average bell and hopper out of place.

What pressure of gas is produced by a top slip depends on the size and the shape of the cavity developed during hanging, as well as the temperature and pressure of the gas it contains, the weight of the suspended column, and the manner in which it drops. There being no means of making direct observation, we can only reason from effect to cause, and the severity of the former has given rise to the assumption that the latter must be some form of explosion. Whether this view is tenable or not depends entirely on how broadly we define the term "explosion." In reality it matters little by what name we call it so long as it does not lead us to a wrong conception of the phenomena of which we are endeavoring to get a clear idea and find an adequate and rational explanation.

Let us suppose that the upper 10 feet of the stock in a modern blast furnace become arrested, *i. e.*, hang. The furnace working normally below, a cavity will at once begin to form, and will increase as fast as the descending column is consumed at the lower end by the process of combustion and smelting. As the descending column shortens, the resistance to the ascending gases through it becomes less, and since the condition of the hanging column is but slowly changing, the gas pressure in the cavity steadily increases. The same is necessarily true of the temperature since the gas passes through material which is getting hotter and hotter as it approaches the zone of fusion. While the increased pressure tends to support the hanging column indefinitely, the increased temperature stimulates chemical action referred to above, and the deposited carbon is gradually consumed. This burning out of the impregnated carbon causes shrinkage of the suspended material and finally results in its dropping or slipping into the cavity below.

It does not require any very considerable stretch of the imagination to suppose that the hanging column, which we assumed to be 10 feet high, to drop like a practically solid plunger into a cavity below 10 or 15 feet deep. This cavity being filled with highly heated gas already under considerable pressure, the necessary immediate effect would most likely be as follows: The hot gas below will be compressed proportional to the weight and momentum of the descending mass, and the partial vacuum formed above will be filled by cooler gas rushing back into the furnace from the gas mains, mingled with more or less atmospheric air drawn in through the leaky bell and poorly fitted explosion doors. Immediately the pressure of the compressed gas is sufficient to overcome the resistance offered by the plunging stock column; it breaks through with force and instantly mixes with the cooler gases above, raising them suddenly to a high temperature, which later may be very materially augmented by the instantaneous combustion of the oxygen present, resulting in a pressure sufficiently sudden and high to produce effects akin to real explosions. The author is not aware that the pressures of these so-called "explosions" have ever been measured, but it is doubtful whether they often exceed 10 or ever reach 15 pounds per square inch. The lesser of these pressures would be quite sufficient to throw any bell and hopper not securely fastened down, clean out of the furnace.

It must not be supposed that top slips always take place in the extreme manner of our hypothetical case just described. Generally the hanging stock drops into the cavity below less suddenly, the phenomena lasting over many seconds and sometimes minutes; nevertheless, considerable quantities of fine ore and coke are thrown out with every slip, and not infrequently large quantities of the coarser material, especially coke, as well. The large furnaces, working principally on Mesabi ore, apparently work by slips only. It is the exception rather than the rule that twenty-four hours pass without appreciable slipping. The quantities of coke and ore that are frequently blown out through the explosion doors and scattered over the premises are appalling. There is one feature about these phenomena which, since their destructive effects have been overcome by structural improvements, makes them less objectionable than would at first appear. The real process of smelting is but very little, if at all, disturbed by them. If it were not for this fact, top slipping would have become intolerable long ago. As it is, large output and acceptable quality are still attainable.

In the light of our present knowledge, top hanging and slipping seems to be attributable to two causes: first, the inherent condition of the ore, and, second, over-exposure. The first can be mitigated by judicious selection and admixture of the ores and proper charging, and the second cause can be largely, if not altogether, avoided, by smelting these ores in furnaces better adapted to their requirements. The modern excessively high furnace is an absurdity when we consider reducibility and other properties, both physical and chemical, of the ores smelted in the majority of them.

Bottom Slipping.—Bottom slipping is a phenomenon quite different from top slipping, and it is due to entirely different causes. Bottom slipping occurs entirely within the zone of fusion and is chiefly caused by temperature variations due to direct variations in the blast temperature, the irregular moisture content, and to changes in the carbon content in the fuel. Irregularity in the composition of the slag aggravated by temperature changes is probably the most prolific cause of hanging and slipping in the lower part of the furnace. Excessively basic slags are more inclined to build up than acid slags. High alumina slags are especially bad. Bottom slips invariably spoil one or more casts of iron, and not infrequently block up the hearth and tuyeres to such an extent with a cold refractory conglomerate of partially reduced iron, slag, carbon dust, lime, and fine coke, that heroic means are required to get the furnace into proper shape again. Not more than a generation ago these bottom slips very often proved fatal to the campaign, or at least required days of sledging and drilling, to get the blast properly into the furnace and the molten iron and slag away from it. The introduction of the oil blow-pipe proved itself of great assistance to the troubled furnace manager, and latterly the electric arc makes playwork out of the task of opening up frozen tuyeres and chilled iron and cinder notches, compared with the sledge and chisel of the olden days.

Scaffolding.—When the accumulations which give rise to bottom slipping cease to come off, *i. e.*, become chronic, we have scaffolding. There can be no doubt that all scaffolding starts in the zone of fusion, and is due to the causes that give rise to bottom slips. If that is true, what would prevent the latter, would make the former impossible. Whether these disturbances can ever be entirely overcome may be questioned, yet there is still so much room for improvement in furnace practice, *e. g.*, in the preparation of the ore and flux, the selection of the fuel, the manner of charging, uniform blowing, desiccation and regular heating of the blast, etc., that many of the troubles now of still too frequent occurrence may be almost if not entirely eliminated.

MECHANICAL CONDITIONS.

Distribution.—The proper distribution of the stock is one of the most important factors in the operation of the modern blast furnace, and this has been greatly emphasized since the introduction of the automatic charging apparatus. There are few conditions in connection with the designing and management of the modern blast furnace, that have given so much trouble and worry to the engineer as well as the furnace manager. While much has been done to overcome the inherent tendency of the skip-hoist to distribute the coarse and fine ore unequally, and much improvement has been made, the charging device that will distribute all the different kinds of material satisfactorily has not yet been invented, or, if invented, has yet to demonstrate its practicability and effectiveness.

The ideal charging apparatus, in addition to fulfilling the paramount requirements of being strong, durable, and forming perfect gas-seal, should be under such control of the man in charge that the material charged, irrespective of its physical condition, can be distributed from the hopper evenly over the entire area of the furnace or practically in a ring against the outer wall, all in the center, or in intermediate circles, or, if need be, in a heap in any desired point of the compass. With such a charging apparatus many of the difficulties now encountered would be entirely avoided, and such irregularities in the settling of the stock which might still occur could be speedily remedied. To be able to use such a charging apparatus to its full possibility it should be supplemented by an automatic stock-level indicator.

Whether the above ideal will ever be reached, or even approximately realized in practice, may be questioned; but there can be no question as to the shortcomings of all existing apparatus. The bell and hopper which fulfils the first three requirements perfectly, falls far short as a distributor because of its narrow limitations and inflexibility, especially in connection with the automatic skip-hoist.

When filling is done by hand it is generally possible, by exercising proper care and judgment, to distribute the stock in a manner most conducive to good results. All the ores should be separated into at least two classes physically, viz., coarse and fine. At hand-filled furnaces this can generally be accomplished without special apparatus, and the stock can be charged into the furnace in accordance with any method the manager may desire, within the limits of the apparatus, which allow great variation, and in this way much can be done to secure uniform working, provided there is sufficient intelligence and vigilance available on the stock-house floor.

BARROWS' METHOD OF CHARGING.

This method was described by Mr. Barrows, Jr., before the Atlantic meeting of the American Institute of Mining Engineers, and may appropriately be called heterogeneous charging.

Assume, for example, that the ore mixture consisted of 25 per cent. of magnetic concentrates, 25 per cent. of fine hematite, 25 per cent. of coarse hematite and 25 per cent. of coarse magnetite, and that a round of ore consisted of 12 barrows.

On this assumption (using the points of the compass for convenience of explanation) the charging would proceed as follows: The coke charge having been lowered into the furnace, then, starting in the north, fill 3 barrows of concentrates side by side, in the northeast quarter; next 3 barrows of coarse hematite, in the southeast quarter; then 3 barrows of fine hematite in the southwest quarter; completing the round with 3 barrows of coarse magnetic ore in the northwest quarter of the hopper. The next round would start in the east with 3 barrows of concentrates above the coarse hematite, next 3 barrows of coarse magnetic ore over the fine hematite, then 3 barrows of fine hematite over the coarse magnetic ore, closing with 3 barrows of coarse hematite over the concentrates. Thus getting every ore into every part of the furnace in regular routine, the coarse and fine ores alternating both as to their vertical and horizontal relation. The main object of this method of filling being to break up the continuity of the gas currents and thus prevent channeling, reduce flue dust and obviate irregularities in general. Mr. Barrows has practised this method with very good success. It is applicable to all hand-filled furnaces, and could be adopted with advantage by all furnaces having to smelt ores differing very much in degrees of fineness.

UEHLING'S METHOD OF CHARGING.

Prior to the advent of the closed furnace tops it was the universal practice to mix the fuel and its burden as much as possible. Every barrow of fuel was invariably followed by a barrow carrying its quota of ore and flux. This method was continued as much as possible after the general adoption of the bell and hopper. At the works in Sharpsville, Pa., where the author first made his acquaintance with the blast furnace, in 1879, the fuel charge consisted of 2 barrows of block coal of 500 pounds each, and 2 barrows of coke weighing 300 pounds each, a total fuel charge of about 1,600 pounds. The 2 barrows of coal were dumped into the hopper opposite, and the 2 barrows of coke into the gaps left between them. Four barrows, of which each carried its proportion of ore and limestone, were dumped over the fuel and all were lowered into the furnace together, thus mixing fuel and ore as much as possible. After studying "Bell's Phenomena of the Blast Furnace," and particularly "Gruner's Analytical Studies of the Process of Smelting," the author came to the conclusion, based entirely on theoretical reasoning, that it was all wrong to mix the ore and fuel in charging a blast furnace; that, on the contrary, they should be separated as much as possible in order to obtain the best results. The theoretical reasons, both chemical and physical, why this should be so, were fully set forth in a paper published in the "Stevens' Institute *Indicator*," in 1884, and again alluded to in my contribution to the discussion of Mr. Barrow's paper read before the Spring meeting of Mining Engineers at Atlantic City, so that it will not be necessary to repeat them here. Briefly, the method of stratified charging consists in filling the fuel and ore in separate layers. The fuel charge should be as heavy as is consistent with the size of the furnace, forming a uniform strata not less than 2 feet deep. In a furnace over 80 feet high, preferably deeper, the ores should be filled on the fuel in strata, beginning with the coarsest and ending with the finest. The limestone, being coarse, should go on top of the strata of coarse ore. It should be kept, as much as possible, from coming in direct contact with the fuel. Different ores of the same degree of fineness should be charged with regard to their capacity for carbon deposition. This very important phase in the phenomena of smelting was very ably discussed by Mr. F. E. Bachman in a paper read before the Colorado meeting of the American Institute of Mining Engineers, but has not received the attention it deserves. In how far the method of charging above briefly outlined can be carried out in practice, depends on local conditions, which would have to be studied on the premises in each case. It may safely be said, however, that there are few furnaces, the running of which could not be very appreciably improved by the application of stratified filling. It can be carried out equally well by hand or any of the approved automatic filling devices.

Gas.—The blast-furnace gas is a most important factor in the process of smelting not only inside, but also outside of the furnace. Inside of the furnace it distributes the heat and reduces the ore to the metallic form. How well it performs these functions can always be ascertained from its temperature and chemical analysis. The first symptoms of irregularities in the process of smelting manifest themselves in the gas. A continuous record of the CO_2 would be of the greatest value to the observant blast-furnace manager. The continuous autographic record of the gas temperature has been found by those who give it attention to be an invaluable aid in diagnosing irregularities in the working of the furnace.

Every furnace man knows that a hot top is indicative of a cold bottom. This will be readily understood from the fact that 100° of heat in the escaping gas is equivalent to over 4·25 per cent. of the heat generated by the fuel burned at the tuyeres. Thus, an indirect fuel loss of from 10 to 15 per cent. may easily take place unnoticed until four or six hours later sharp cinder and inferior iron reveals the fact that something went wrong.

In addition to revealing internal conditions of the furnace, the autographic gas temperature record indicates the charges that go into the furnace, both as to time and number, and is, therefore, a most valuable check on the stockhouse operation.

In a paper, entitled "The Blast Furnace as a Power-Plant," the author endeavored to show by simple process of calculation that, under conditions of best average fuel consumption, viz., 2,000 pounds of coke per ton of iron, and proper treatment and utilization of the gas, there would be a surplus of at least 800 horse-power per ton of iron produced per hour. Or, in other words, a blast furnace of a daily capacity of 250 tons, or, in round numbers, 10 tons per hour, should have a surplus of gas over and above all furnace requirements, sufficient to generate 8,000 horse-power in any of the available types of large gas engines. Other investigators, notably Mr. B. H. Twait, who is the pioneer in the field of direct utilization of blast-furnace gas in the gas engine, have come to similar conclusions.

Since publishing the above calculations, the author has had opportunity to investigate the blast-furnace gases at a number of the large iron and steel plants, and has found that his figures were very conservative; that from 1,000 to 1,200 horse-power is nearer the actual surplus power that should be available.

In view of these facts, and the practically more weighty fact, that on the continent of Europe, especially in Germany, there is scarcely a furnace plant where not from several to many thousand horse-power are generated by blast-furnace gas direct, is it not strange that, with one laudable exception, nothing at all has been done to save the enormous waste now going on because of the irrational application of the blast-furnace gas?

From 45 per cent. to 50 per cent. of the heat value of the fuel used in the process of smelting in the blast furnace is contained in the escaping gases, of which 35 per cent. should be sufficient to heat the blast and produce the power to run the furnace and all its mechanical accessories. In spite of this enormous theoretically demonstrable surplus heat energy, the fact remains that, at the majority of the blast-furnace plants, hundreds of tons of coal are burned annually to assist the gas in generating the necessary steam for the power required, and it is the exception rather than the rule that the desired blast temperature can be regularly obtained from the stoves, notwithstanding the fact that both stoves and boilers have from time to time been increased both in size and number. The sole reason of this deplorable condition is due to the fact that the uncleaned gas cannot be efficiently utilized. It is just as irrational to burn the impure gas as it would be to attempt to burn coal mixed with all the slate and rock that is dug and raised with it from the mine.

The partial purification employed at the majority of plants in the dry way is based on irrational methods and carried out by primitive and inadequate means, and rarely more than the coarsest of the flue dust is separated from the gas. The attempts at washing are generally carried out by half-way methods, which, although they remove much of the finer dust, are liable to contaminate the gas to such a degree with moisture that the harm overbalances the good accomplished.

The subject of gas purification is too vast to do more than allude to it at this time. I consider it the most important problem before the blast-furnace manager and engineer to-day. Even if we leave out of sight the value of the surplus gas for power purposes, the saving in extra boiler and stove equipment, in wear and tear on the latter, in time lost directly and indirectly because of stoppages for cleaning, inadequate steam and heat, coal burned, and cost of labor for cleaning stoves and boilers, etc., etc., would more than justify the cost of a gas-washing equipment that would properly cleanse the gas.

LONG-DISTANCE LINES IN FRANCE.

The British consul at Lyons states that the transmission of electric power over considerable distances is developing, and it is stated that 3,000 horse-power is to be transmitted from the Alps, distant 100 miles from Lyons, for the working of the tramway company. The British vice-consul at Grenoble reports that a considerable quantity of electric power is still to be purchased in that district at a cheap rate for the purpose of establishing manufactories of all kinds.

UTILIZATION OF WASTE COAL.

The greater care now exercised in utilizing the output of anthracite coal is shown in the saving and marketing of the small sizes, which were formerly thrown away. In some collieries the proportion of these small sizes, which are used chiefly in making steam, runs up to 40 per cent. of the total shipments. It is evident also in the working over of the old culm banks, from which a considerable quantity of merchantable small coal is obtained. The shipments from the washeries, in fact, have been over 2,000,000 tons in the past two years. It is not impossible that, in a few years more, even the dust, or culm, will be saved and utilized in making power-gas, or in generating electricity at or near the mines, for transmission to points where it is needed.—*Eng. and Min. Jour.*

CHEMICAL SECTION.

Stated Meeting, held Thursday, November 10, 1904.

The Sulphur Dyes.

BY J. MERRITT MATTHEWS, PH.D.,
Lecturer on the Chemistry of Textiles and Pottery, Franklin Institute.

There has probably been no branch of chemical research which has yielded more abundant fruit during the past fifty years than that relating to the production of dyestuffs. It is not my intention in this paper to go into the general development of this subject, as that would require a far too lengthy discussion in itself, so I will limit my remarks to the consideration of one of the latest progressive movements dealing with the manufacture and use of the synthetic dyestuffs. By this I refer to the, comparatively recently introduced "sulphur dyes," as they are now commonly referred to.

The original representative of these colors was discovered a number of years ago, in 1873, by Croissant and Bretonnière, and it was given the name of "Cachou de Laval." It was prepared in rather a peculiar manner by the fusion of organic vegetable matter, such as sawdust, etc., with sodium sulphide and sulphur. The resulting product was a porous, lumpy mass of a brownish-black color and readily soluble in water, and decomposing in moist air with the liberation of some sulphuretted hydrogen. It was found that unmordanted cotton could be dyed by this substance a brown color, though the dyestuff, it is true, had but slight tinctorial properties compared with the other artificial dyes, yet the color obtained with it was very fast to washing. It was on account of its fastness that the new coloring matter received a considerable amount of attention. The general method of applying the dyestuff was to boil the cotton material in a solution containing the coloring matter together with a rather large proportion of common salt. This was for the purpose of forcing on the fiber more color, as otherwise it took a very large proportion of the dyestuff to produce any depth of color. Even under these conditions, however, the dyestuff does not exhaust from the first bath to any great degree. By after-treating the dyed color with a solution of potassium bichromate, the intensity of the color is somewhat enhanced and the general fastness of the dyestuff is improved. By a similar after-treatment of the color with bluestone or copper sulphate, the fastness of the dyeing to light appears to be somewhat increased.

It was also found that cachou de Laval when dyed on cotton acted as a mordant towards a large number of other coloring matters, such as most of the common basic dyes, the vegetable dye-woods, and the alizarine dyes. The shades obtained with the basic dyes, however, are not as fast to washing as the original cachou de Laval, also those with the vegetable dyewoods are not so fast to light; but the shades obtained in conjunction with the alizarine dyes are as a rule fast to both washing and light.

Owing to the small tinctorial powers of cachou de Laval, it never became of much commercial importance in dyeing. It was looked upon chiefly as a curiosity among the artificial dyestuffs, particularly on account of its peculiar method of manufacture.

A number of years passed before the sulphur dyes received any further development. It was not until about 1893 that the French chemist Vidal publicly announced his discovery of a black sulphur dyestuff wich he called Vidal black. This coloring matter was made by fusing para-amido-phenol with sulphur. The product obtained was of uncertain composition, but was found to yield black colors on unmordanted cotton, and was especially characterized by its great fastness. The dyestuff, however, was liable to decomposition on exposure to the air, and presented certain practical difficulties in dyeing so that at first it was not received with much favor. A number of years passed in the development and perfection of this coloring matter and a study of its properties and possibilities, until it had passed beyond the stage of experiment and finally attained commercial success. This led the attention of other dyestuff chemists, especially those of the large German color factories, to the investigation of the sulphur dyestuffs, with the result that great activity was soon displayed in the preparation of new colors, and the purification and modification of those already known. A large number of these dyes have appeared in trade during the past five or six years, and the range of colors has been so extended as to include various shades of black, brown, blue, green, olive, yellow, and orange colors; a red color among the sulphur dyes is still lacking, the nearest approach being the so-called orange, and certain very red shades of brown. All of these colors are applied in about the same manner and are only used on cotton, giving shades which are very fast, especially to washing and acids, and on this account are very desirable products.

The sulphur colors usually appear in trade in the form of blackish lumps, which are hygroscopic and rapidly deteriorate on exposure to the air, especially in the presence of moisture. On this account the dyestuff should be used up as soon as possible after the package is opened. Recently, however, some of these dyes have appeared in the form of dry powders and are not so hygroscopic, being mixed with some suitable drier, and consequently are not so liable to deteriorate. The manufacturers also seem to be preparing these dyes in a much purer and more concentrated form so that their tinctorial power is considerably increased. The sulphur dyes nearly all smell more or less of sulphuretted hydrogen, especially when moistened or dissolved in water; they also, as a rule, contain more or less sodium sulphide.

Some of the sulphur dyes may be dyed directly on cotton with nothing but the solution of the coloring matter; in other cases, however, a considerable amount of sodium sulphide must be added to the dyebath for the purpose of bringing the dyestuff into proper solution; there is also added some soda ash for the purpose of correcting any hardness which may be present in the water and which would cause a precipitation of the coloring matter. In general these dyes are applied in about the same manner, as regards the manipulation of the cotton materials, as when other dyes are employed. Care must be taken, however, in most cases, not to have any copper or brass fitting present in the dyeing vats, as the dyestuff is decomposed by these metals; iron and lead, however, may be used without danger. Some of the dyes require an after-treatment with certain metallic salts, especially potassium bichromate or copper sulphate, in order to yield the full development and fastness of the color. In their general fastness they far surpass the other colors available for cotton dyeing, and are comparable in fastness to indigo and aniline black. They are especially suited to the dyeing of material contained in cotton and woolen fabrics, where the cotton is dyed first and the wool is afterwards dyed in acid baths, as these colors will stand the treatment with hot acid baths. The dyestuff does not cause any injury to the cotton fibre, though the dyed goods should be carefully washed in order to eliminate all excess of sodium sulphide, the retention of which by the fibre would eventually cause a weakening; but beyond this, the dyestuff itself does not weaken the goods. One drawback to these colors, however, is that in dyeing them the cotton is liable to become somewhat harsh to the feel, although the fibre may be softened by suitable treatment with oil, or soap baths. The sulphur blacks are especially adapted for the dyeing of fast blacks on hosiery, as also are the brown colors, as the dyestuff stands the repeated washings and the effect of the acid perspiration to which the color of hosiery is subjected.

Correspondence.

THE PROPOSED COMBINATION OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY WITH HARVARD UNIVERSITY.

TO THE EDITOR OF *The Journal of the Franklin Institute:*

Sir:—In connection with the proposed combination of the Massachusetts Institute of Technology with Harvard University, the following authoritative statement of foreign opinion (translated from *Zeitschrift des Vereines Deutscher Ingenieure* of September 24, 1904) is of interest:

"At a meeting of the Union of German Engineers, held at Munich, September 12th, with the participation of thirty eminent representatives of technological schools and universities, as well as of other schools and of industries, the following resolutions were adopted:

"(1) It is not advisable, so far as can be foreseen, to attempt to meet the need of new technological schools by the addition of technological faculties to universities, but rather by the establishment of independent institutions; for the technological schools would be hindered in their independent development by attaching them to universities. This separation should not, however, impede the welcome development of intellectual good-will between the two institutions. The attachment to universities would also in no way involve economies of consequence.

"(2) The Union of German Engineers stands now, as before, by its expression of 1886, as follows:

"'We declare that the German engineers have the same needs and will be subjected to the same judgment as to their general culture as the representatives of other professions based on higher scientific education.'

"In this view we rejoice as the conviction more and more gains ground that a considerably greater significance is to be attributed than before to mathematical and natural science as a means of culture. Knowledge of these branches is becoming more and more an indispensable constituent of general education. The predominantly linguistic education now received by the majority of our gymnasium graduates does not satisfy the demands which must be made on the leading classes of our people, in particular, in respect to the increasing significance of economic questions."

TECHNOLOGICAL GRADUATE.

Book Notices.

De Laharpe. Notes et Formules de l'Ingenieur et du Constructeur-Mechanicien. By a committee of engineers of the Ecole Centrale and the Ecole des Arts et Métiers. Fourteenth edition, revised, corrected and considerably enlarged, containing 1,350 illustrations, followed by a technical vocabulary in French, English and German. Paris: E. Bernard. 1,800 pages ($4\frac{1}{2} \times 7$ inches). 12f. 50.

The full title indicates that this is a reference book for engineers covering the matter usually found in mechanical engineers' reference books published in this country, with the addition of some of the data collected in similar works devoted to civil engineering. The scope of the work is further extended by the introduction of data on several branches of industrial technology.

The volume is somewhat awkward to handle, due to its thickness, and its appearance is marred by the display of advertisements on the leather cover and sides. These features, however, are probably due to the effort to produce an extensive work at a minimum cost.

The source of the subject-matter should be a sufficient guarantee of its excellence, but in some instances a better selection could have been made. The section on springs is a case in point: Here fifteen pages are devoted to a discussion of elliptic and some unusual forms of helical springs, with tables of carrying capacity and deflection, but the ordinary helical spring of round wire, which is perhaps more widely used than any other form, is not mentioned.

The copious index and the technical vocabulary at the end of the volume are particularly valuable features to the engineer who desires to consult foreign practice.

In an insert the publishers extend the usual privilege to those who have purchased a previous edition of receiving the latest at a cost of 6f. 25 on the return of the old copy. L. E. P.

Franklin Institute.

[*Proceedings of the Annual Meeting, held Wednesday, January 18, 1905.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 18, 1905.

VICE-PRESIDENT WASHINGTON JONES in the chair.

Present, 76 members and visitors.

The annual Report of the Board of Managers, and Appendices embracing the reports of the Committees of the Board and the Institute, the Sections, and the Trustees of the Elliott-Cresson Medal Fund, were presented and, on motion, were formally accepted.

The Chairman then introduced Mr. St. John Clark, General Inspector of Designs of the New York Rapid Transit Commission, who gave an extended account of the plan and method of construction of the New York Subway.

Mr. Clark was followed by Mr. F. R. Slater, principal Assistant Engineer to the Electrical Director of the Interborough Rapid Transit Company, who gave a description of the electrical power and light equipment of the Subway. Both papers were profusely illustrated.

Mr. Fred. E. Ives, of New York, followed with a communication describing "A New Form of Diffraction Grating for the Spectroscope," in which he described a method that he had devised for making replicas of diffraction gratings, possessing a degree of accuracy approximating that of the originals, which made it possible to furnish students in spectroscopy cheaply with an apparatus of this character of a refinement hitherto unapproachable.

Mr. Ives' invention was referred to the Committee on Science and the Arts for further investigation.

The speakers of the evening were tendered a vote of thanks.

The Tellers of the election made their report of the result of the annual election, held this day between 4 and 8 P.M., whereupon the Chairman reported the following members elected, viz.:

For President	(to serve one year)	JOHN BIRKINBINE.
" *Vice-President*	(" three years)	WASHINGTON JONES.
" *Secretary*	(" one year)	WM. H. WAHL.
" *Treasurer*	(" ")	SAMUEL SARTAIN.
" *Auditor*	(" three years)	WM. H. GREENE.

For *Managers* (to serve three years).

EDWIN S. BALCH,
WALTON CLARK,
THOS. P. CONARD,
CHAS. HENRY HOWSON,

LOUIS E. LEVY,
CHAS. LONGSTRETH,
ISAAC NORRIS,
COLEMAN SELLERS.

For *the Committee on Science and the Arts* (to serve three years).

A. W. Allen,
Hugo Bilgram,
Amos P. Brown,
Frank P. Brown,
W. W. Canby,
Kern Dodge,
W. C. L. Eglin,
E. Goldsmith,
Lewis M. Haupt,
Lucien E. Picolet,
C. J. Reed,
Jas. S. Rogers,
Geo. P. Scholl,
E. Alex. Scott,
Coleman Sellers,
Harrison Souder,
H. W. Spangler,
A. H. Stewart,
D. Eppelsheimer, Jr.,
Martin I. Wilbert.

The meeting passed a vote of thanks to the Tellers.

Adjourned.

Wm. H. Wahl,
Secretary.

Report of the Board of Managers for the Year 1904, With Appendices Embracing the Annual Report of the Various Committees and Sections.

Presented at the Annual Meeting of the Institute, held Wednesday, January 18, 1905.

To the Members of the Franklin Institute:

The record of the eighty-first year of work of the Franklin Institute, as presented in detail by the accompanying reports of the Officers, Chairmen of Committees and of Sections, shows continued interest in all branches. These reports, which are briefly summarized in the following statement, emphasize the amount of the gratuitous work of members, which the Board appreciates and is gratified to acknowledge.

Endowment.—The Board realizes the generosity of those who have contributed to the funds in the hands of the Trustees, now amounting to $90,000, and of those who have bequeathed to the Institute, property or money, which will ultimately add probably $60,000 to the permanent fund. But the total assets of the Institute, which are, or which may be, available for its maintenance, are far from sufficient to be considered as a recognition of the service which the Franklin Institute has rendered to the advancement of Science and the Mechanic Arts.

During the year efforts have continued to obtain sufficient money to secure better accommodations for our unexcelled technical library, and to increase the invested fund, so as to permit of extending the usefulness of the Institute. Some of these overtures were unfortunately interfered with by premature publicity given to them, although such publicity was evidently presented in a spirit of good-will.

Your Board, which you have continued in office, will endeavor to encourage the co-operation of those whose financial ability may make it possible to overcome the disadvantages under which the Institute work must be prosecuted.

Although located in Philadelphia, the Institute's influence and work is world-wide, and its investigations, made without cost, have been for individuals, the City, the State and the Country, hence, an ample endowment would not be merely the advancement of a local institution.

The Library of technical literature, numbering 58,000 volumes, and nearly as many more pamphlets, charts, maps, etc., is the Institute's chief asset, and the rapid increase in publications demands constant additions and larger outlays for maintenance.

The increase of 2,400 titles during the past year, while gratifying, has not kept the Library up-to-date, and binding, rebinding, indexing, etc., have been curtailed for want of ample funds.

The Journal has been well supplied by papers read at ten meetings of the Institute and thirty-four meetings of its sections; and 546 foreign and domestic technical periodicals regularly received, mostly in exchange for the *Journal*, indicate the esteem in which it is held.

The Meetings of the Institute and Sections and the two courses of popular lectures have been well attended, and much interesting information disseminated. The services rendered by those who presented papers, or delivered lectures, are gratefully acknowledged.

The Committee on Science and the Arts.—Thirty-one medals and awards of merit were granted by the Committee on Science and the Arts in disposing of forty-three cases. An equal number of pending cases suggests the activity of this committee, which by unselfish devotion has helped many meritorious inventions with deserved recognition, or by friendly counsel discouraged misguided inventors.

Membership.—No radical change is indicated by the roll of members, numbering about 1,600, the additions practically offsetting the withdrawal losses by death, etc.

In the absence of sufficient endowment the support of the Institute falls mainly upon its members, and a liberal increase in membership is the immediate method of enlarging the influence and augmenting the usefulness of the Institute.

Your individual attention is directed to the desirability of promptly paying annual dues. In apportioning the income for each year the Board endeavors to utilize it to best advantage, and default in dues works serious disturbances to its administrative plans.

Schools.—Four hundred and seventy-four students received instruction during the year in the schools connected with the Institute, and under the supervision of the Committee of Instruction. Of these 349 are in the drawing school, 87 were students of machine design and 38 studied naval architecture. The attendance was less than in 1903, when the limited space available was over-crowded.

FINANCIAL STATEMENT FOR 1904.

Balance on hand January 1, 1904	$371 78
Receipts in 1904	26,237 81
	$26,609 59
Payments in 1904	24,554 51
Balance on hand January 1, 1905	$2,255 08

The Permanent Endowment Funds of the Institute, January 1, 1905, are $140,855.95, an increase in 1904 of $51,000.

The action of the Institute in promoting the introduction of the Gill School City System of Civic Education into the public schools of Philadelphia resulted in eliciting the unqualified endorsement and earnest advocacy of the movement from the public press, and in enlisting the active support of a very considerable number of our leading citizens. The School City movement has thereby been brought up to a point where its further progress is largely dependent on the official action of our municipal school authorities.

During the past year the Institute has suffered the loss of a number of active and prominent members by death. The following list of names of deceased members is hereto appended, although it is probably not entirely complete:

Edward W. Clark, Luther L. Cheney, S. Lloyd Wiegand, Henry M. Boies, Howard White, Jr., William Weightman, Samuel Wetherill, Henry George Ormsby, Col. A. M. Miller, U.S.A.; T. A. Mackinnon, Morton McMichael, Thomas L. Luder, Dr. B. B. Gumpert, Dr. Thomas M. Drown.

By order of the Board,
JOHN BIRKINBINE, *President.*

REPORT OF THE LIBRARY COMMITTEE FOR THE YEAR 1904.

To the President and Members of the Franklin Institute:

The Committee on Library respectfully submits the following annual report:

The contents of the Library have been increased during the past year by 2,397 titles. In 1903 the accretions numbered 4,924, but the present falling off is due almost entirely to a great reduction in the number of pamphlet additions, which amounted to 662 in 1904 as against 3,179 in the preceding year. Pamphlets are obtained almost exclusively as gifts, many being sent in with the view of their inclusion in a permanent repository; others as contributions from friends of the Institute. It is in this latter respect that we have this year been less fortunate than in the preceding twelve months, the accretions of pamphlets from general sources remaining fully up to the average.

The additions during 1904 comprised:

1,174 bound volumes.
517 unbound volumes,
673 pamphlets,
1 chart,
1 photograph,
31 drawings.

These accretions were derived as follows:

115 through the Bloomfield Moore Fund,
30 " " Memorial Library Fund,
48 " " M. Carey Lea Fund,
50 " " James T. Morris Fund,
20 " " general Library appropriations,
91 " " binding of periodicals,
64 " " *Journal* of the Institute,
17 " " exchange of duplicates,
83 " an old exchange account,

and the remainder through deposits from the Federal and State governments, through contributions from societies and institutions at home and abroad and through gifts from individual donors.

The Ogden N. Rood Donation.—Of the gifts from individuals, a most welcome and valuable addition to the Library was that made by Mrs. Rood, widow of the late Ogden N. Rood, Professor of Physics at Columbia University, who died in 1903. Mrs. Rood's gift comprises the following important items:

Annalen der Physik und Chemie—
  Poggendorff series, Vols. 1 to 160, 1824 to 1877.
  Wiedemann series, Vols. 1 to 69, 1877 to 1899.
  Drude series, Vols. 1 to 9, 1900 to 1902.
  Beiblätter, Vols. 1 to 26, 1877 to 1902.
  Fortschritte der Physik, Vols. 1 to 57, 1845 to 1901.
  Verhandlungen der physikalischen Gesellschaft, 1888 to 1902.
  American Journal of Science, 1860 to 1902.

A number of unbound volumes of these periodicals are being bound and will shortly be made accessible for reference.

Through the generosity of Mr. Alfred C. Harrison it has become possible for the Committee to complete the set of specifications of United States Patents without expending any of its regular appropriation in that direction. These reports were five years in arrears and Mr. Harrison expressed his readiness to defray the cost of purchase and gave the sum of $216 for the purpose. These important documents will now be up-to-date and will include the specifications of the year 1904, most of which are still to be issued.

Other considerable gifts of books and pamphlets were afforded to the Library by Drs. Harry F. Keller, William H. Greene, Walter N. James; Messrs. George S. Barrows, John E. Carter, E. P. Cowell, W. J. Donohugh, Morris Ebert, Richard W. Gilpin, Stephen Greene, E. B. Gumpert, Carl Hering, J. Y. McConnell, C. P. Roepper, Samuel Shoemaker, W. Thum, John C. Trautwine, Jr., U. C. Wanner, and by the Crocker-Wheeler Company, the McGraw Publishing Company, Lewis F. Shoemaker Company, and Wilson, Harris & Richards.

The present contents of the Library are as follows:

	57,956	volumes (bound and unbound),
	42,579	pamphlets,
	2,864	maps and charts,
	690	drawings and designs,
	1,244	photographs,
	192	newspaper clippings,
	31	manuscripts,
a total of	105,556	titles.

The list of periodicals currently received by the Library now numbers 546, an increase of 13 during the past year. The large majority are obtained in exchange for the *Journal* of the Institute, the present increase being all derived from that source.

Binding.—Binding and rebinding were effected during the past year as follows:

92	volumes of completed serials,
11	paper-bound books,
3	rebindings,
106	total.

Three hundred and sixty-four volumes are still in the binder's hands and much further work of this nature is urgently demanded. An expenditure of $500 in this direction could be made with great advantage to the Library. An especially pressing need of this nature is the binding of the sheets of the great mass of British Patent Specifications. The movement, mentioned in last year's report, for an advance in this direction by means of contributions to a fund specially for this purpose was halted by reason of other demands, and the situation remains unimproved.

The Pamphlet Library.—The pamphlet section of the Library remains as yet in a condition leaving much to be desired. The pamphlets are stored on shelves in the south room, on the first floor of our building, where they are well preserved but practically unavailable through lack of proper classification. Many of these pamphlets are of great value as records of important transactions, and as treatises not otherwise published, and to make them accessible for consultation they should be thoroughly classified and represented in the card catalogue of the Library. This work will require the services of a trained assistant for a considerable period of time. An expenditure of some $1,500, covering wages, boxes and cards, would about accomplish this most desirable improvement of the Library.

Increase of the James T. Morris Fund.—Of the various special funds now sustaining the Library, that established by Mr. John T. Morris, in February, 1899, with a foundation of $1,000, and since augmented by several additions of $1,000, has again been enriched by his contribution on December 27th, ult., of another sum of $1,000. The income of this fund has been made available by Mr. Morris for the purchase of books on the subject of mechanics, and this section of the Library is already largely reaping the benefits of his good-will.

Evening Attendance.—The attendance of the Library after business hours in the evening shows a continuance of the falling off noticeable in recent years. The Library was open on 80 evenings during the past year with a total attendance of 238, a decrease of 155 from the preceding year. This condition emphasizes nothing so much as the fact alluded to in our last report, that the location of the Institute in the heart of the business section of the city, while leaving it amply accessible in the daytime, places it far out of the channels of active intercourse after nightfall, and renders it in that respect correspondingly less available for that large class of the community which has only the evening hours at its disposal.

Louis Edward Levy,
Chairman.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS FOR THE YEAR 1904.

To the President and Members of the Franklin Institute:

The Committee on Science and the Arts has the honor to submit the following statement of the work done during the year just closed:

To facilitate the work of assigning the applications to appropriate sub-committees, the personnel of the whole Committee was classified as to professional occupations or trades, and it was found in a general way that the qualifications were distributed about as follows:

Mechanical Engineers, chiefly	15
Electrical " "	9
Chemists or Doctors of Medicine	8
Graphic Arts	3
Geologist and Mineralogist	1
Metallurgist	1
Plumber	1
Pure Science	3
Naval Architects	2
Photography	3
Civil Engineering	2
Insurance	1
General Utility	2
Miscellaneous	6

Many of the members were fully qualified to render good service outside of their specialties and were so assigned. It appears, however, that there is a notable weakness in the section of Civil Engineering, which may be due to the fact that most of the applications are for mechanical devices and relate especially to machinery, steam, electrics or some branch of the Arts or Manufactures, so that this may be more apparent than real as a source of weakness in the Committee.

As will appear in the Appendix, in detail, the total number of cases submitted to the Committee during the past year was 86, of which 50 per cent. were finally disposed of, and of these 38 received advisory reports or awards. Of the 27 medals granted, 5 were for the "Elliott Cresson," 15 for the "John Scott" and 7 for the "Edward Longstreth."

In this connection it may be well to record the fact that the Courts have decided finally the authority of the Franklin Institute to determine and make the award of the Elliott Cresson Medal.

The large amount of disinterested expert service rendered by the members of the Committee cannot be stated in figures, but some idea may perhaps be gained of its distribution by reporting the number of cases on which service was accepted by the individual members, thus:

Four of the members, exclusive of the chairman, could not serve at all.

7	served	on	1	case.
11	"	"	2	cases.
16	"	"	3	"
9	"	"	4	"
4	"	"	5	"
3	"	"	6	"
2	"	"	8	"
1	"	"	10	"

Changes in the Personnel of the Committee.—It is with regret that the Committee is obliged to report the resignation of four of its efficient and experienced members who find it no longer possible to serve the Institute in this capacity, so that their resignations were reluctantly accepted and the vacancies supplied by the election of new members.

The resignation of Dr. Henry Leffmann, so long and favorably known, left a vacancy filled by the election of Dr. W. J. Williams, of the Frankford Arsenal, Bridesburg, Philadelphia, Pa.

Mr. Wilfred Lewis, one of our most highly esteemed mechanical experts, left a vacancy which will be filled at the next annual election.

The vacancy caused by the retirement of Prof. Edgar Marburg was filled by the election of Mr. A. W. Allen, of the American Bridge Company, Philadelphia, and the resignation of Mr. C. W. Pike was filled by the election of Mr. Richard L. Binder, of Philadelphia, Pa.

It is the painful duty of this Committee also to report the loss by death of one of its oldest, most esteemed and ablest members, Mr. Luther L. Cheney, whose conservative judgment and long experience have been of the greatest service to the Committee and the Institute, and have endeared him to the membership as a warm personal friend.

Meetings.—During the year 11 sessions were held, of which 10 were regular and 1 was special. There was an average attendance of 20 members, the highest being in April, when there were 30 present; and the lowest in September, when there were 16 present. An analysis of the attendance shows the following interesting statement:

Of the total membership of 60—

11 were absent from all meetings,
2 members attended once,
9 " " twice,
5 " " three times,
7 " " four times,
4 " " five times,
2 " " six times,
7 " " seven times,
7 " " eight times.

In closing this report the chairman desires to extend his grateful thanks to the members of the Committee on Science and the Arts, as well as to the efficient Secretary of the Institute, for their active co-operation and cordial support in the conduct of its affairs during the past year.

Respectfully submitted,
LEWIS M. HAUPT,
Chairman for 1904.

PHILADELPHIA, PA., January 2, 1905.

APPENDIX.

DETAILS OF THE COMMITTEE'S WORK IN 1904.

Number of cases pending on December 31, 1903		38	
Number of cases proposed in 1903:			
(*a*) By application	33		
(*b*) By reference from the Institute	9		
(*c*) By vote of the Committee	5		
(*d*) By vote of Sections	1		
Total number of new cases in 1904		48	
Total number of cases before Committee in 1904 .			86

Total number of cases finally disposed of in 1904,	43	
{ Of which there were: Adopted, 40 Dismissed or withdrawn, . . . 3		
Cases pending December 31, 1904	43	
		86

The forty-three cases disposed of were determined as follows:

Award of Elliott Cresson Medal	5
Award of John Scott Legacy Premium and Medal	15
Award of Edward Longstreth Medal of Merit	7
Award of the Certificate of Merit	4
Reports made advisory	7
No awards	2
Cases dismissed or withdrawn	3
Total	43

REPORT OF THE COMMITTEE ON MEETINGS FOR THE YEAR 1904.

To the President and Members of the Franklin Institute:

The Committee on Meetings, with the assistance of the Secretary of the Institute, has arranged the programs of the ten meetings held during the past year. In performing this task the Committee has sought to secure subjects of general public interest, and, judging from the generally good attendance, its efforts in this direction have been reasonably successful.

As was noted in last year's report, the growing importance of the work of the Sections renders it increasingly more difficult for this Committee to retain for the monthly meetings the conspicuous place they used to occupy before the institution of the Sections, and as then stated it will continue to be the policy of the Committee "to reserve the meetings as far as possible for the presentation and discussion of subjects of general interest and importance."

Respectfully yours,

WASHINGTON JONES,
Chairman Committee on Meetings.

PHILADELPHIA, PA., January 2, 1905.

REPORT OF THE COMMITTEE ON PUBLICATIONS FOR THE YEAR 1904.

To the Board of Managers.

GENTLEMEN: The Committee on Publications has nothing of special importance to communicate with reference to its operations during the past year. With the appropriation made by the Board of Managers, it has been able to continue the publication of the *Journal*, and to maintain its respected position. The amount of material offered for publication by the Sections, the Institute meetings and the several Committees, has been ample to supply the Committee's requirements. The circumstance that the *Journal*, for a number of years, has been in fact what its name implies, the Journal of the Franklin Institute, should be highly gratifying to the Managers and the members, indicating as it does, a steady maintenance of the scientific activities of this Institute.

Harry W. Jayne,
Chairman of Committee on Publications.

Philadelphia, Pa., January 2, 1905.

REPORT OF THE COMMITTEE ON INSTRUCTION FOR THE YEAR 1904.

To the Board of Managers.

Gentlemen: The interest shown by the members of the Institute in the popular lecture courses given in co-operation with the Central Branch of the Young Men's Christian Association has been quite satisfactory to the Committee, the attendance at the lectures having been excellent. As heretofore, the services of the eminent lecturers who have contributed to make the Committee's work successful, have been given without compensation, and the thanks of the Board are due to them.

The schools have been well patronized, although the number of pupils enrolled has fallen off somewhat from the high figures of the previous year. The comparative data for the years 1903 and 1904 make the following exhibit:

	1903.	1904.
Drawing School	445	349
School of Machine Design	107	87
School of Naval Architecture	85	38
	637	474

With the sanction of the Board, the important step was taken, during the past year, of increasing considerably the teaching force, by the appointment of a number of eminent specialists as professors and lecturers on special subjects. The change thus instituted has already begun to exhibit its advantages in giving substantial assistance to the various branches of the Institute's activity.

Respectfully submitted,

Wm. H. Wahl,
Chairman of Committee on Instruction.

ANNUAL REPORT OF THE COMMITTEE ON ELECTION AND RESIGNATION OF MEMBERS FOR THE YEAR 1904.

To the Board of Managers of the Franklin Institute:

The Committee on Election and Resignation of Members respectfully submits the following membership figures for the year 1904.

The Committee has continued its special systematic efforts to obtain new members.

The Committee's work, supplemented by that of several members who have from time to time presented a new name, and by the very considerable assistance rendered by Mr. Robert C. H. Brock, member of the Board, has been enabled to place on the rolls the names of 101 new members. The losses through death, resignation and non-payment of dues are noted in the accompanying schedule, showing that, numerically, the membership remains about the same as at the close of 1903. The Committee again urges the membership in general to participate in the work of increasing the numerical strength by inducing new persons to join. The result of the presentation of one new name by each member is easy to calculate.

The membership at the close of 1903 was	1,605
New members secured in 1904	101
	1,706
Loss by death, resignation and non-payment of dues	109
Members at close of 1904	1,597

ALEXANDER KRUMBHAAR,
Chairman.

PHILADELPHIA, January 2, 1905.

REPORT OF THE COMMITTEE ON SECTIONAL ARRANGEMENTS FOR THE YEAR 1904.

To the Board of Managers:

Your Committee on Sectional Arrangements respectfully reports that during the year 1904 the Sections of the Institute held thirty-four meetings, nearly all of which were devoted to the consideration and discussion of subjects of strictly technical or scientific interest. The pages of the *Journal* afford the best evidence of the value of the work thus accomplished.

The Committee is pleased to be able to report that the interest of the members in this branch of the Institute's activity is well maintained. The report of the secretaries is appended hereto.

JAMES CHRISTIE,
Chairman Com. on Sectional Arrangements.

PHILADELPHIA, January 2, 1905.

APPENDIX.

To the Committee on Sectional Arrangements:

The several Sections have had thirty-four meetings during 1904, all being joint sessions of the entire Section body. In respect of attendance and the general character of the subjects discussed, the past year will compare favorably with any of its predecessors. The *Journal* has been enriched by numerous contributions of value from this source.

Some modification of present methods will be introduced in 1905, for the purpose of keeping more prominently before the members the idea of the separate organization of the individual Sections, which, naturally, has been forced more or less into the background by the placing of all the special routine work hitherto done by each Section in the hands of an Executive Committee appointed by the Committee on Sectional Arrangements. With the restoration of these functions, it is believed that the only serious criticism that has been brought against the "joint session" plan as now in vogue, will be met satisfactorily.

WM. H. WAHL,
for the Secretaries.

PHILADELPHIA, January 3, 1905.

Committee on Science and the Arts.

Abstract of proceedings of the stated meeting held Wednesday, January 4, 1905.

PROF. LEWIS M. HAUPT in the chair.

The following reports were adopted:

(No. 2312.) *Improved Cap-screws and Bolts.*—The Cleveland Cap-screw Company, Cleveland, O.

ABSTRACT: The cap screws made by applicant company are intended to be used for the same purposes and in the same manner as cap-screws have heretofore been used. The novelty contained in these products consists in the fact that the inclosing together of the head and body of the screw is done electrically, die-drawn stock prepared for the purpose being the material used, and the heads made to conform to the United States or Franklin Institute standard heads.

(The details of the several processes of manufacture are interesting, but cannot well be abstracted. The report will in due course be published in full.)

The Committee made a number of tests—tensile and torsional— of samples of these cap-screws, with results that were quite satisfactory, confirming substantially those published in the descriptive pamphlets issued by the manufacturers.

The report recommends the award of the John Scott Legacy Premium and Medal to David T. Kurtz, the originator of the method. (*Sub-Committee:* J. Logan Fitts, Chairman; Charles E. Ronaldson, D. Eppelsheimer, Jr.)

The following reports were considered and referred back to their respective sub-committees for various reasons.

(No. 2331.) *Electric Protective Devices.*—The International Burglar Immunity Company, Philadelphia.

(No. 2345.) *Products of the Flexible Compound Company*, Philadelphia.

The following passed first reading:

(No. 2310.) *A System for Quantitative Calorimetry.*—Dr. Persifor Frazer, Philadelphia.

(No. 2329.) *Knitting Machine.*—Edward Parkinson, Philadelphia.

(No. 2342.) *Hydraulic Letter-copying Press.*—Walter A. Rosenbaum, New York.

(No. 2348.) *Elevator Safety Devices.*—The Standard Elevator Interlock Company, Philadelphia.

PROTEST: The protest of Messrs. Seitz & Barnes objecting to the grade of the award granted to Seitz for his improvement in "Coal loading and screening machinery," was reported back from sub-committee No. 2294, with a favorable recommendation. The report was accordingly amended by the grant of the Edward Longstreth Medal of Merit.

The Annual Report of the Committee for 1904 appears elsewhere. W.

Sections.

[*Abstracts of Proceedings of Stated Meetings.*]

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—*Stated Meeting*, held Thursday, January 5, 1905, 8 P.M. Dr. Henry Leffmann in the chair. Present, 47 members and visitors.

The annual election for officers, which was held, resulted as follows: President, Henry Leffmann; Vice-Presidents, J. W. Ridpath, U. C. Wanner; Secretary, Martin I. Wilbert; Conservator, William H. Wahl.

Dr. J. L. Borsch presented a communication on "A New Bi-focal Lens." Dr. Borsch gave a brief historical sketch of the origin and development of bi-focal lenses, which, he said, had been originally devised by Dr. Benjamin Franklin when he was in Paris, and described an improved lens of this character which he had devised.

A paper by Mr. C. Chester Ahlum, describing the microscopical and chemical differences between sumac and tobacco, was, in the author's absence, read by the Secretary. The subject was illustrated by several lantern slides and microscopic preparations.

Mr. Charles S. Rabineau, representing the Eastman Kodak Company, of Rochester, made demonstrations with a new developing machine for "Velox" paper.

The meeting was closed by an exhibition of miscellaneous lantern slides illustrating various features of the St. Louis Exposition and views taken in the mining regions of Idaho and Colorado. They were described by Mr. W. W. Canby. Mr. Balderston, of Williams, Brown & Earle, gave a demonstration of the various capabilities of the recently acquired microscopic attachment to the Institute's lantern.

On motion, the bi-focal lens of Dr. Borsch, and the "Velox" developing machine, were referred to the Committee on Science and the Arts for investigation.

Adjourned.

M. I. WILBERT,
Secretary.

ELECTRICAL SECTION.—*Stated Meeting*, held Thursday, January 12, 1905, 8 P.M. Mr. Thomas Spencer in the chair. There were present 45 members and visitors.

The following officers were elected to serve for the year 1905: President, Thomas Spencer; Vice-Presidents, W. C. L. Eglin and Charles J. Reed; Secretary, Richard L. Binder; Conservator, Wm. H. Wahl.

The president introduced the speaker of the evening, Mr. C. J. H. Woodbury, American Telegraph and Telephone Company, Boston, who read a carefully prepared paper in which the subject of "Telephone Line Engineering" was treated very thoroughly.

The paper, with discussion thereon, was referred to the Committee on Publication.

The meeting passed a vote of thanks to the speaker.

Adjourned.

RICHARD L. BINDER,
Secretary.

JOURNAL
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FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA,
FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CLIX, NO. 3. 80TH YEAR. MARCH, 1905

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

ELECTRICAL SECTION.

Stated Meeting, held Thursday, January 12, 1905.

Telephone Line Engineering.*

BY C. J. H. WOODBURY, Boston, Mass.,
Assistant Engineer American Telephone and Telegraph Company.

The purpose of all applications of electricity, excepting those of industrial chemistry, is warranted, because it overcomes the impediments of distance.

The amount of capital invested in electric lines, and the rapid depreciation to which they are subjected, renders their construction a matter of importance.

Methods of standard aërial and underground-line construction were shown, and also numerous views showing the methods of overcoming the difficulties through mountains, over rivers, spanning gorges and the savannahs in the southern part of the country.

The growth of the Bell Telephone System has progressed at the annual rate of 29 per cent. compound interest during the past five years, which is over three times the rate of increase during the preceding fifteen years.

The cause of this augmented growth was stated to have been the increased value of the telephone service resulting from the construction of long lines connecting even villages and small towns, as well as cities, in one intercommunicating system, which afforded facilities for that conference which is the fundamental element in commercial transactions.—THE EDITOR.

The wonders of the telephone as the most subtile of physical apparatus, yet so simple as to be the only electric device operated without skill, an invention without precedent which has also escaped improvement, has worthily been the theme of frequent portrayal, which has also been devoted to that concentration of applied science upon the switchboard and the transmitter, each of them essential adjuncts in the development of the telephone system.

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* Illustrated by lantern slides showing methods of telephone line overhead and underground construction.

The salient characteristic which justifies all commercial applications of electricity, except those of industrial chemistry, is that it overcomes the impediment of distance, and it is essential that the conductors spanning these long extents, free from direct supervision, shall be as permanent as possible in order to maintain conditions of constant service.

The amount of capital amassed in the approximately 4,000,000 miles of line construction necessary to connect together in a unity the subscribers of the Bell telephone system is of itself a warranty as to the importance of the subject; while the rapid depreciation to which most of this property is subjected requires both technical skill and business judgment to decide upon the most judicious methods of construction of this vast plant, amid varying circumstances of natural conditions and commercial use, in order to reach the most economical point of investment.

Analyze the general problem as one may, and standardize the general methods to cover a wide range of circumstances, yet there are exigencies and varying conditions which require the exercise of that type of constructive engineering which "does things."

"The picture is first rate, but we built the bridge last night," said the Maine lumberman in the army to his West Point commander.

The application of mathematical principles is essential to any constructive work which is not merely a repetition of precedents, and the ordinary precedents of safe construction have been established upon the wrecks of past failures perhaps for generations agone.

In this paper it is proposed to submit largely by lantern slides some of the engineering difficulties which have been met in line construction and the manner in which these obstacles have been overcome, as well as ordinary methods of standard construction.

The electrical problems form a subject apart from that of this paper.

The increase of every commercial application of electricity to meet the demands to supply service to patrons has been so great that an essential portion of every problem in constructive electricity must take into consideration provisions for future growth as well as the inevitable depreciation.

POLES.

Although 45 per cent. of the wires are on poles, the total extent of the pole lines exceeds the length of the underground conduits, as the latter are used only in cities where the conduits contain a greater number of lines to reach the concentration of patronage.

The extent of the pole lines is shown by the fact that in the Bell telephone system there are approximately 6,300,000 poles, and about 1,000,000 are required annually for replacement and for extension of lines.

A number of years ago a large collection of logs, known as the Joggins raft, was towed from Nova Scotia to New York, and this raft contained many long poles which were not suitable for masts.

Some of these long poles were used for the largest pole line ever built, at the westerly side of New York City, and carrying 250 wires each. At the present time there are single underground cables comprised of $4\frac{8}{10}$ times as many conductors, and under the main streets in the principal cities are conduits of sufficient capacity to carry 400 times as many wires as one of these pole lines.

The typical methods of setting poles will first be shown by some representations from standard drawings.

Where the soil is not firm enough to sustain a pole imbedded in the usual manner, security may be obtained by extending the supporting area by plank at the bottom of the excavation and filling the hole with concrete, or braces may rest upon a platform placed on the surface of the ground, and in some instances these platforms rest upon piles.

In other instances these braces rest upon plank placed underground, or, in place of a single pole, they are set in pairs, either vertical or joined at the top and connected by strong wire at the ground, making what is known as an A pole.

When the line changes its direction or there are other causes to make a lateral pressure against a pole, it is secured by braces or by guys, either running to an anchorage in the earth or to some other object.

When a telephone line is built in or near cities, the close connection with supplies and labor renders that portion of the work comparatively easy, but in the construction of long distance lines across country, connecting various cities, towns and villages within speaking distance of each other, it is necessary to provide means for the execution of the work on an independent basis.

In a suitable locality a camp consisting of a number of tents is pitched, one of them being a dining tent; another is where the cook holds sway, and the engineers' tent, where such details as must be left until the work is in progress receive attention, while several tents are necessary to provide for the sound sleep which awaits the close of a good day's work.

If the route runs through a wooded country, a wide swath is cut in the forest and the post holes may be made by the diggers, or in other instances a charge of dynamite deposited in an auger hole makes quick work, the greatest relative gain being in compact clayey soil.

Meantime the poles have been brought to their sites by teams, and then moved to the exact place by the help of an axle mounted on a pair of wheels termed a dinkey; gains are cut and the cross-arms attached before they are raised, either by all hands with pikes giving a long push, a strong push and a hard push all-together, to change the old aphorism, or if the country is not too rough to permit, a portable derrick mounted on a wagon is drawn to the site, then the horses are taken from the pole and pulling at the rope quickly raise the pole.

Then the derrick wagon is drawn to the next pole and the work proceeds rapidly.

When the line changes in direction, the pole is rendered more secure by guys and the pole line is ready for the wires which are payed out from a number of reels in a wagon, thence passing through a set of guiding holes, which prevent snarling.

The final attachment of the wires to the insulators on the cross-arms is very carefully done, because it is necessary that the wires should be drawn to an extent that they should not sway against each other, and yet not so tightly that the contraction in cold weather would put a stress on the wire which would produce danger of breakage, for at these small amounts of dip in the wires a slight difference in the length of the line will cause a great variation in the stress.

The stresses to which a telephone pole is subject are the result of many and variable combinations of live and dead loads upon a beam fixed at one end and loaded near the other end.

There is scarcely anything in engineering construction so actively the subject of depreciating conditions.

The top is exposed to the weather, and the important section near the surface of the ground is the portion most energetically attacked by decay. The wood is assailed by animal life, whether it be gnawing by horses in town, or the perforation by woodpeckers in remote districts. Poles in wild countries are bitten by bears in search of bees, whose humming is imitated by the vibration of wires, and it is said that in India the tigers use the poles to sharpen their claws upon after the manner of their second cousin, the domestic cat, but with so much more vigor that the poles become weakened.

Not only are they wrecked by storms, but freight-car roofs frequently fly off and strike the poles edgewise with destructive results.

Iron poles are but rarely used in this country, the principal condition governing their selection being on some lines in prairie countries in the West where campers are so prone to cut down wood poles for fuel, that tubular iron poles have been substituted. In Europe there are many iron poles, and in tropical countries infested with white ants it is necessary to use iron poles or to attach the wires to living trees.

In the Philippines the United States authorities are planting large straight trees to serve as living attachments for telephone lines, as seasoned wood poles decay quickly under the conditions of tropical moisture.

Antiseptic methods for treating poles as a preventive against decay and the attacks of insects have not been so general in the United States as in Europe, as the relatively sparse settlement and distances between cities having the elaborate plant necessary for treatment would make the transportation of the poles for treatment and back to the sites where they are to be used a prohibitive expense.

However, poles treated by creosoting have been used in this country wherever transportation conditions between the saw mill, the treating plant and the sites where they are to be used will permit.

These conditions apply to certain portions of the South, where Southern pine is sawed to dimensions and then treated.

As the cost of this treatment is based on the volume of the timber, these poles are sawed to such proportions of taper as to give the most economical volume of timber to resist the stresses to which the pole may be subjected. The weakest section of these poles, as computed, is from 8 to 10 feet above the ground.

While gravelly soil will hold a pole to the limit of its strength, it is necessary to build lines in many places where such conditions do not occur. The New Orleans and Mobile line, along the north shore of the Gulf of Mexico, traverses marshes composed of soft mud which extends to a great depth, upon which a rank sedge grass grows 12 to 15 feet in height, whose coarse roots form a compact mass about a foot in thickness.

In order to prevent this line from being injured by the fires which rage among these marshes in the early spring, the grass is kept cut to a width of 100 feet along the route.

It has been possible to sustain poles along this route by bolting heavy cross-pieces across them at the ground level, having cut an opening among the roots through which the butt of the pole can be inserted, and then the pole is braced as occasion may require, sometimes in four directions, each of these braces being supported on a cross-piece at the marsh level. In some instances a pair of, or even three, poles are used, each being attached to the same cross-arm.

Similar methods are used in building the lines across the New Jersey flats, although the conditions are not so severe as at some places farther south.

At the Tybee marshes, near Savannah, Ga., the ground is so soft that it cannot be walked upon, and the men engaged in building the line were obliged to lay a line of boards to proceed along the route. When a pole was to be set, cross-pieces were temporarily attached to it near the lower end, and men standing upon these supports "jounced" in unison while the pole was held vertically by pikes.

Under this human pile-driving the pole sinks rapidly, but the mud is so adhesive that in a short time the pole is securely held.

When ground is too wet and soft to permit digging, poles are frequently set by hewing their butts to wedges, and while the pole is held in a vertical position it is grasped by cant hooks and twisted back and forth, causing it to sink, like the ordinary motion used in boring a hole in wood with a brad awl.

When once set, the pole is either held securely by braces or guys, or it may be made firm by driving a wood curb around it, excavating the mud between the curb and the base of the pole and filling the space with concrete.

In sandy soils, particularly in New Jersey, poles are set on the principle of the jet pile, wherever there is a supply of water.

A half inch pipe about 6 feet in length is temporarily attached to the side of the pole, with its lower end at the butt. The other end of the pipe is attached to a garden hose, and when the pole is up-ended the stream of water makes a quicksand into which the pole sinks until the water is shut off, and the pole is sustained by pikes until the water settles, leaving the pole securely held by the sand, which becomes water-packed around it.

In mountainous countries the ledges are an impediment to excavations for poles, and although dynamite is frequently used, yet poles are set upon rock without excavation and a large number of stones are piled around them in such quantities as to grip the poles securely, although guys are generally necessary.

A pole line is not designed merely on the basis of the stresses to which the pole is subjected in drawing the wires to the necessary tension, for in most northern climates the sleet will at times form upon the wires until they become icy cylinders perhaps 3 inches in diameter, and the problem is not that of the mere added weight, for the force of the wind blowing against this icy sail applies a greater horizontal load, which combines with gravity and produces a resultant force in a diagonal direction, greater than either of the contributing units.

An ice-laden line swayed by the wind may be successfully resisted by the poles until the oscillations of the pendulum reach a synchronism with that of the vibration of some pole on the line which responds in like manner to the rhythm of the consecutive blows across the direction of the line, until the cumulative impact breaks this individual pole. Then adjacent poles are relieved of the pull on one side, and the excessive unbalanced stress breaks them.

Such is the story of a wrecked aërial line, broken by stresses not included in the ordinary course of events, and which must be provided for by large factors of safety.

It is indeed fortunate that meteorological conditions furnishing in sequence rain at just above a freezing temperature, and meeting a colder stratum, without wind, near to the earth, but followed by a gale, are rare and generally are limited to a small area, for they present conditions which cannot be fully circumvented.

Officers of the Weather Bureau reported in connection with a sleet storm of unusual severity, that there had not been similar conditions in that locality for twenty-three years.

The breakages of lines resulting from a severe storm in Southern New England, a few years ago, revealed the fact that the damage was confined to the valleys of the rivers emptying into Long Island Sound, while the storm did not appear to be of sufficient severity to cause any damage to the lines on higher land.

It is claimed that sleet never forms to a destructive extent on the wires in certain portions of the northerly part of the United States, and this may be one of the instances of the rarity of such occurrences.

A pole is not to be compared to a mast upon a vessel, for these extreme conditions of severe exposure to telephone lines occur in winter, when the ground is frozen, and holds the base of the pole rigidly, while a vessel in a gale heels when struck by puffs and the sails "spill the wind," and in this manner the masts sustain exposure to winds which would break them if held rigidly to long-continued impact.

PREVENTION OF CROSSES.

The most undesirable occurrences in connection with the wreckage of aërial lines are the disturbances resulting from the contacts of different electrical systems with each other, when the various lines are so near as to collide, when one or both break.

While the currents used on the telephone system are so minute as to be without power of damage, yet their wires, in crossing the lines of electric lighting or power systems, may in making short circuits cause serious mishaps to the electric lighting or power plant, and in any event materially interfere with the service.

While the imposition of an electric lighting or power current upon a telephone line would destroy the fine apparatus, and perhaps cause other injuries, were it not for the protectors for the purpose of preventing these foreign currents from reaching the subscribers' installations, or the telephone central stations.

It is far better to prevent the occurrence of harmful conditions than it is to abate their injurious results by a temporary sacrifice of the continuity of the service, for the operation of a protector serves to open the telephone circuit and to prevent the use of the instruments for the time being, until the lines are cleared and the protectors renewed.

The remedy against the liability of such crosses is the simple one stated by a judge of a United States court, in which the decree was given that the distance between the high and low potential lines should be equal to that of the highest pole, so that in the event of the falling of a pole the wires would come short of reaching the other line. In many instances congestion of electric service and narrow streets prevent any such wide separation, and it becomes necessary to take every precaution for substantial construction.

It is necessary for such different lines to cross the others' routes, and in such instances provision against collision is made by the use of extra heavy construction, thoroughly bracing and guying the poles, and arranging against overhauling of the lines in case of their breakage; also guarding the wires so that those on the upper line could not fall over the ends of the cross-arms in case of their separation from the points of support.

As high-tension wires are of larger diameter and fewer in number, their poles should be higher at the crossover.

The crossover span should be so short and at such height that in case of breaking next to an insulator, the remaining portion of the span wire should not be long enough to reach to the lower line.

The necessary height of poles, or the impracticability of placing them in such positions as to provide for the short crossover spans, may sometimes render it unfeasible to adopt this construction, and a grill of hard-wood slats placed at frequent intervals across a pair of steel wires or cables between the two spans interposes a screen which prevents a broken wire on the upper span from reaching the lower span.

In some instances, where there are but few wires in each line, they are attached to the same pole, and the contact is prevented by a frame-work carrying guard wires below the upper line.

It is not as a general principle advisable to use a single pole crossover.

House tops at the first furnished an attractive route for aërial wires, and some of the fixtures for carrying these wires were of great size, but the framing of most buildings is ill-suited to resist the excessive stresses due to such loads, and the introduction of underground conduits has furnished suitable means for such main conductors, but it is necessary to carry branch wires over the tops of houses in order to reach patrons to whom the wires cannot be led in any other manner.

In place of the old timber constructions, suitable iron pipe frameworks are now generally used.

Other continuous structures are used for conveying large numbers of wires, especially bridges and the elevated railways in cities.

AERIAL WIRES.

The aërial wires are so visibly in evidence, and often to an obstructive extent, that they may be cited as the portion of the system which naturally receives especial attention from the public.

Before presenting instances of construction, it is worth while to submit two matters of principles of aërial lines and materials.

The tension on a line suspended between a pair of horizontal supports varies with the sag and is at a minimum when the sag amounts to $\frac{7}{20}$ of the span, and the tension increases whether the sag is greater or less than this proportion.

For example, with No. 12 hard-drawn copper wire, weighing 173 pounds to the mile, and being ·104 inches diameter, and having a span of 130 feet, the minimum tension of 3 pounds would occur if the sag was 43 feet 6 inches, while it would slowly augment with increase in the sag, and if nature had furnished a chasm deep enough for the experiment, it would be expected to reach its breaking tension of 550 pounds at a depth of 16,470 feet, or 3·17 miles.

On the other hand, the increase in tension proceeds rapidly as the wire is drawn to approach a straight line, the breaking tension occurring at a sag of 1½ inches.

As a comparison with this instance of the stresses in a local line, in the case of the No. 8 hard drawn copper wire, ·165 inch in diameter and weighing 435 pounds to the mile, as used on long-distance telephone lines, when the span is 150 feet the minimum tension occurs at a dip of 52 feet 6 inches, when it is only 8¾ pounds, and in like manner, as in the foregoing instance, its breaking stress of 1,328 pounds would be reached at the slightly less dip of 16,100 feet, or 3·04 miles, still too great to admit of confirmation by direct experiment; but if the wire was pulled until the sag was 2$\frac{2}{10}$ inches, it would require the breaking load of 1,328 pounds.

It is desirable that the wires should be drawn tight enough to prevent them from swaying against each other; but it is important that they should not be drawn so tight that the contraction during extreme cold weather should cause the wire to break.

The temperature is carefully noted when lines are being drawn, and the sag is left in accordance with a table based on a factor of safety of five computed for the usual lengths of span throughout a range of natural temperatures.

Natural Temperature Fahrenheit.	Length of Span of Hard-Drawn Copper Wire in Feet.					
	75	100	115	130	150	200
	Sag in Inches.					
— 30	1	2	2½	3½	4½	8
— 20	1½	2½	3	4	5	9
+ 10	1½	3	3½	4½	6	10½
+ 30	2	3	4	5½	7	12
60	2½	4½	5½	7	9	15½
+ 80	3	5½	7	8½	11½	19
+ 100	4½	7	9	11	14	22½

When a wire is laden with sleet, the strain lengthens the wire and the increased sag diminishes the tension sometimes to an extent sufficient to save the wires, which would otherwise be broken were it not for this elongation.

HARD-DRAWN COPPER WIRE.

The electrical advantages of copper over iron could not be utilized for aërial wires, because commercial copper has so little resilience that it will continually stretch under its own weight and become attenuated to an extent that it will break, until Thomas B. Doolittle produced the hard-drawn copper wire which is now in universal use on aërial lines. The treatment consists in omitting the annealing processes during the latter portion of drawing the wire, but it deviates from the usual method by attenuating the wire by smaller gradations at the latter die plates. The rate of diminishing the wire is wholly an empirical one, at first determined by long and thorough experimentation, and as the hardening occurs for the most part near to the surface, the tensile strength per square inch of section is greater with smaller than with larger wires.

For example, No. 8 wire is ·165 inch diameter and has a tensile strength of 62,100 pounds to the square inch, while No. 12 wire, ·104 inch diameter, has a tensile strength of 64,600 pounds to the square inch.

In comparison with commercial copper wire, which has a tensile strength of about 32,000 pounds per square inch, the strength is nearly doubled. The modulus of elasticity is increased from 12,000,000 pounds to 19,000,000 pounds, or about 60 per cent., while the elongation before rupture is reduced from 35 per cent. to 1¼ per cent.

It will be noted that this remarkable change in the mechanical properties of copper wire is produced entirely by manipulation and without the admixture of any alloy.

Its electrical conductivity is practically the same as that of commercial wire drawn from the same ingots, the slight increase being due to the change in the molecular condition of hard copper.

Mr. Doolittle did not patent this valuable process of the manufacture of hard copper, which has extended the limit of electrical transmission of speech four times the distance available with iron wire, and has been of incomparable value in other electrical service, and the award to him of the Edward Longstreth Medal by the Franklin Institute in 1898 was an act of most suitable recognition of an invention which has been usefully applied to the service of mankind throughout the world wherever electric wires are spanned.

The relative cost of iron and copper wire is not a measure of the comparable expense of such lines in actual service, as copper does not have, under these conditions of exposure, an oxide of high resistance, and its life has not yet been determined. The value of copper scrap from wrecked or reconstructed lines is about 2 cents a pound less than that of new wire, while galvanized iron line wire costs about 4 cents a pound, and when taken down is of no value, and is generally thrown upon a dump.

The rusting of iron wire at the joints adds materially to the resistance of the line.

A few years ago an iron telephone line crossing swamps near Norfolk, Va., was reported open after a thunder storm, but an inspection showed that there was no break in the continuity of the wires; however, electrical tests revealed that the joints insulated the various sections of the wires from each other, the strokes of lightning having produced oxides of high resistance.

LONG SPANS.

Where lines traverse mountainous districts or water courses it is frequently necessary to build spans of great length, using either one of the special bronzes or steel wire for the purpose.

The Connecticut River at Middletown is crossed by wires having a span of 1,350 feet, suspended between a steel-trussed tower 185 feet high on the east side, and a similar tower on the bluff on the west bank is 85 feet high.

From Enfield to Windsor locks the Connecticut is spanned by a suspension bridge consisting of two steel cables 1 inch in diameter and 955 feet long, to which are fastened 2-inch by 3-inch joists 4 feet 4 inches long set 12 inches on centers. On this bridge are laid four cables containing 100 pairs of wires. The tower on the west bank shown in the foreground is 45 feet high, and the one on the east bank 33 feet high.

The St. Francis River, near Madison, Ark., is crossed by a span of 1,000 feet, with the wires supported upon steel-trussed towers 100 feet in height, as it was necessary that the wires should be clear of steamers on the river, which has a varying level of 30 feet between flood and drought.

At the Raritan Canal crossing, near New Brunswick, N. J., a 60-foot span is raised 112 feet above the canal to avoid the shipping.

There are numerous long spans crossing ponds and rivers not used for navigation at which it is not necessary to erect such high towers or to draw the wires up to a small dip to avoid masts.

Long spans are frequently strung in cases of emergency, as when the flood of June 2, 1903, carried away the bridge crossing the Kaw River at Kansas City, Mo., and also the wires attached to it, a span of wires 900 feet in length was immediately suspended between high spars erected on either bank.

The Missouri River at this city is crossed by a span of 1,500 feet, consisting of fifty No. 8 bronze wires suspended between steel-trussed windmill towers 80 feet in height.

The Delaware River at Yardley, Pa., is crossed by an aërial span of 1,300 feet in length with a dip of 10 feet. In all instances, it is necessary to use great care in the anchorage of these long spans, for a rigid attachment would cause the wires to become broken when swayed by the wind.

In some instances it has proved sufficient to carry the wires through semicircular grooves cut into a curved wood saddle upon each of the towers at the ends of the span, but the recurrence of breakages has been stopped in other cases only by attaching the saddles to springs which will yield to the impact resulting from swaying wires.

The very long spans constructed across the Mississippi, Hudson and Susquehanna Rivers have been advantageously replaced by submarine cables.

The most spectacular work in line construction has been done among the mountain ranges of the West.

Lines have been built against the face of cliffs bordering deep canyons, where it was necessary to incline the poles so that the tops carrying the wires overhang the deep abyss, in order to avoid icicles and avalanches falling down the precipice.

In building telephone lines through this mountainous country, a couple of poles are slung like panniers on the sides of two or three mules tandem, and these sure-footed animals will carry them along the rough trails.

The wire is wound in great lengths in connecting coils, which are placed on the sides of the saddles of a train of pack mules, which are thus connected on one side by wire from coil to coil, around the front of the foremost mule and thence back along the other side of the train.

By removing the last pair of coils and unreeling, and thence in turn to the next coil, the pair of wires for a metallic circuit can be laid down along a route.

The Mosquito Pass, near Leadville, Colo., was crossed at an elevation of 13,130 feet by a line of poles which were set only 15 feet apart at the more exposed places, but even this construction did not resist the storms of winter.

Telephone lines were afterwards maintained through this Alpine exposure by an expedient as far out of the ordinary as the celebrated venture of Lord Timothy Dexter in sending warming-pans to the West Indies, and that was by replacing the line of poles by submarine cable carried to this elevated site in continuous coils, as in the case of wire transportation over the mountain trails upon a train of mules, and laid in trenches among the rocks to avoid any disturbances from avalanches.

There have been instances when it was necessary to make expeditions to these altitudes in severe weather to made repairs.

The rough valleys through which the routes pass are picturesque in summer, but in winter the snow accumulates to such depths that linemen attend to their duties on snowshoes, reaching the lines on 25-foot poles as if they were wire fences.

Among these mountains are ravines which can be crossed only by long spans, where the difficulties are increased by the inclination between the opposite ends of the span, which produces severe end thrusts at the points of support, which are built of three poles capped by cross-beams, which must be held by the most secure guying.

A few of these spans will illustrate the conditions necessary to be overcome in order to extend the telephone to these isolated mountain towns, at all times difficult of access, and during the long winter a hermitage were it not for this telephone service.

Imogene Basin, Col., at an elevation of 13,700 feet, is crossed by a span of 950 feet, which inclines at an angle of 27°. Near Telluride and the Tomboy mines, ravines are crossed by similar long spans.

A surveying party, arranging for the extension of some of these lines, found the snow to be 20 feet deep in these basins in the middle of July, while avalanches had rolled down opposite sides of a valley, leaving a narrow pass bordered by snow and ice 100 feet in height.

These lines, running from the valleys up to great elevations on the mountains, are charged with atmospheric electricity, particularly in winter, which is discharged to earth by bridging retardation coils across the lines and grounding the central part of the coils.

The surveying party noted that these disruptive discharges of static electricity occurred about sixteen times a second, producing a continuous sound which could be heard by one near to the wires. The mountain appeared to be enveloped by static electricity, the poles and the engineers' transit glowed with St. Elmo's fire, and an irritation was felt at the head, and the hair would fly up if the hat was removed.

This electric envelope did not appear to extend to the ground, as one was entirely free from any sensations when lying down, but if, while in such a position, a hand was raised to about 3 feet above the ground, a sharp sputtering sound of static electrical discharges would occur.

IMPEDIMENTS TO WIRES.

Trees are a serious impediment to wires, and although it is at times feasible to arrange for a severe trimming, yet for the most part such excisions must be made in moderation and the lines arranged to go over or under, or, like the priest and the Levite, "pass by on the other side."

At one of the electric light conventions, a speaker was asked what method was used by his company for trimming obstructive branches, and he replied: "For the most part the electrical method."

While a high-tension circuit, carrying sufficient current, will burn its way through a branch of a living tree, yet the self-interest of all electrical companies, without regard to other important considerations, impel them to the utmost care in avoiding trees.

Considerable damage is done to electric lines by trees felled during gales, and at St. Louis, May 27, 1896, and also at Minneapolis, August 20, 1904, tin roofs have been bodily stripped from buildings and placed upon the telephone wires, the metal contacts connecting various telephone lines causing confused jabber at any listening telephone unequalled since the days of Babel.

Telephone lines are patrolled by inspectors alert to observe incipient conditions of weakness, threatening decay of poles, trees growing too near approach to the lines, possible hazards to the service from other electrical wires, and especially in cases of severe storms is the utmost vigilance necessary to take prompt measures in case of any occurrence which will prevent the subscriber, perhaps a thousand miles away, from having the conference which he has the right to expect when he takes the telephone from the hook.

Useful as the telephone may be in affording facilities for communicating between different portions of a city, there are other methods of reaching one's townspeople—messenger, mail, or, like the leader in a child's game, "send myself;" but there is no equivalent for the question and the answer which can be exchanged between persons 1,500 miles apart, their voices reaching each other in less time than if they were conversing across a room; or, to give a concrete example, the time for telephonic transmission over the 1,064 miles between Boston and Chicago is ·006 second, while the distance that the voice is transmitted through the air in that time is 6½ feet.

There are many thousands of miles of telephone lines without poles, for the business of lumbering and the wood-pulp industry is conducted over telephone lines traversing the forests from tree to tree through the wilds.

By the use of the telephone the methods of log-driving have been changed for the better. The facility of communication between different gangs along a stream enables the logs to be conveyed without the disturbances caused by jams, which can be prevented by prompt action, and also avoids the destruction of timber, which would otherwise result from the use of dynamite to relieve these jams.

Smaller and more rapid streams, hitherto unsuited for lumbering, have been utilized by the construction of dams, which husband and release the water as may be considered necessary by the men perhaps miles below, who speak through the telephone to those operating the gate at the dam.

The first telephone line of anything beyond a local line was in a wild country, for during the winter of 1878 telephones were used on the telegraph line connecting the signal service observers at the station on the summit of Mount Washington, N. H., to the base, while the first telephone central station with subscribers, in the present sense of the term, was opened at New Haven, Conn., January 28, 1878, although switchboards were used by associated groups of a few persons prior to that date.

One of the most useful applications of the telephone is in connection with the life-saving service, whose telephone lines extend along the shore, and the patrolman carries a small portable telephone which he can connect at fixtures upon the side of frequent poles, and in this manner communicate to the life-saving station for routine report and to summon help in case a vessel is in peril off the shore.

A telephone is a portion of the elaborate system of police signal in cities, while in smaller towns the simpler form of a telephone in a box serves the purpose.

For the household it bestows an assurance of safety in the facility which it gives to all, the opportunity to summon the fire department or other help in case of emergency.

UNDERGROUND CONDUITS.

The number of wires necessary to supply the patronage in cities so far exceeded the possible capacity of pole lines along the streets that it became necessary to place them underground, and this required the development of the underground conduit and the telephone cable as new arts.

While 55 per cent. of the telephone exchange wires are underground, yet the great number of wires in these conduits in comparison with those on poles makes the number of miles of pole lines throughout the country seventy times the length of the streets occupied by underground conduits.

While no other ratio may give an adequate impression of the predominant use of the telephone for communication over long distances, yet in comparison with the length of steam railroad rights of way in the United States, the length of Bell telephone pole lines exceeds that of the railway system by over 26 per cent.

The first experimenters upon underground systems attempted to make them water-tight, and also insulators, such as a solid mass of asphalt concrete in which wires, frequently without insulation, were imbedded.

The lack of satisfactory results caused the Bell Telephone Company to begin the development of the work under Mr. Joseph P. Davis, Chief Engineer, on the principle of providing a conduit of substantial construction containing ducts in which the cables could be placed or withdrawn, and relying upon the conduit merely to provide a protection against injury.

A conduit was built in Boston in which the ducts consisted of 3-inch iron casing pipes, treated by the hot coal tar process to defend against rusting, which were imbedded in a concrete of eight parts of fine roofing pebbles to only one of cement, and this has remained in good order for twenty-two years.

The manholes were made of brick, covered on the outside with coal tar, and the foundations laid on plank covered with coal tar before the bricks were laid.

This construction was afterwards used in New York, but there was not a sufficient supply of iron casing pipe in the market to supply the demand, and as it was necessary that the work should proceed as rapidly as possible, other materials for ducts were also used.

Logs were bored from end to end and then squared parallel to this core, and sockets and plugs to fit cut at alternate ends to bring the cores securely in line. The wood was treated by the creosoting process before the logs were laid.

Cement-lined sheet-iron pipe imbedded in concrete was also used in large quantities.

At a later date vitrified clay conduit was introduced, and has been extensively used.

Other materials and methods have been used, notably wood pulp tubes treated with indurating materials to render them impervious to water and a defence against decay.

Tunnels for underground cables have been dug through the soft limestone underlying the city of St. Paul, and one of the largest engineering works of the day is the extensive system of tunnels under the streets of Chicago, which has provision for cables as well as the transportation of material.

In rare instances short tunnels are built, as under the canal and railroad at Trenton, N. J.

In addition to the usual difficulties which beset all constructions under highways, the size of the manholes or underground chambers which afford places for splicing cables or changing their direction, as well as leading them from the conduits to centers of distribution, where the individual pairs of wires branch to the service of patrons, the size of these manholes render other occupants under the streets serious obstructions.

When underground conduits were first built in an Eastern city, the engineer prepared sets of standard drawings, and so many were the modifications rendered necessary by other underground work that only one manhole was built in conformity to the standard design.

A conduit 260 feet long, containing 13 ducts, at Seventeenth Street and Allegheny Avenue, Philadelphia, was successfully lowered 12 inches at one end and 18 inches at the other, on account of a change in the street grade.

When large underground work, such as subways, are built in cities, the changes in conduits as well as lines of pipes and sewers present difficulties of which it can only be said in the present available limits, that the changes were made.

While a trench was being dug for an underground conduit in Rochester, an unexpected ledge was uncovered, there were no facilities for that work at hand, and a steam roller was hired to supply steam for the drills, and the ledge was soon blasted away.

Underground conduits have wrought a great change in the housing of the telephone central station plant, as the rigidity of an underground system requires that the distributing centers should be of equivalent permanency, and the telephone plant could not in such cases be subject to the mutations of leased property, but must own the buildings.

Therefore fireproof buildings have been constructed by telephone companies all over the country, until the Bell Telephone system owns the greatest number of fireproof buildings of any single interest in the country, and its holdings of buildings and land in cities make it a vast realty enterprise.

If the underground conduits remove conductors from vicissitudes of decay of poles, and exposure to storm and the hazards of foreign currents, yet the underground conduits have their share of mishaps.

Breaks in water pipes or sewers disturb the foundations of these conduits, rain storms flood them, illuminating gas percolates into them, waiting to be ignited by a spark from a horse's shoe at some leak around a manhole cover, or it may be lighted by men going to work in a manhole with a lantern looking for trouble—and finding it.

The superficially attractive proposition of joint conduit systems, particularly in connection with a scheme of municipal conduits for electric wires, has been attended by serious occurrences.

Crosses among high tension conductors in cables occur from time to time, and if the wires of signalling systems were exposed in the narrow limits of a manhole, they would be disabled.

In one city where an inclusive conduit was laid by the municipality, the work was fortunately in good hands, and the manholes were built very large, with the cables of various classes placed on supports upon opposite sides of the manholes, and the cables containing high tension wires enveloped with split underground tile conduit tied together.

The attempt of a municipality to force a Bell Telephone Company into an inclusive underground conduit system under circumstances which were considered to expose their cables to hazardous conditions, gave rise to litigation in which the contentions of the Telephone Company were fully sustained by the Supreme Court of that State.

CABLES.

The necessity for cables was coincident with the decision that underground conduits must be constructed on the "drawing-in" and not on the "built-in" system, and at about the same time it was foreseen that aërial cables must replace the open wiring in cities wherever there were a great number of local wires, on account of their compactness, and greater resistance to storms. For electrical reasons, it is necessary that open wiring must be used for long telephone lines.

The first telephone cables, both aërial and submarine, are believed to have been those used at Philadelphia in 1881, and at that time experimental constructions were being made at Providence, Brooklyn and Boston.

In the latter city parallel rubber-covered wires, giving conditions of such great electrostatic capacity that a mile was the utmost limit of telephonic transmission, were tried, but when about a third of a mile was inserted in a telephone line, subscribers complained that their instruments were becoming worn out, as they could barely hear; and the induction between the parallel wires was so great as to transmit cross-talk between the various circuits.

The induction was stopped by placing the wires in twisted pairs, but the problem of insulation with a low static capacity required long experimentation by many persons. Mr. W. D. Sargent, of Brooklyn, tried paper insulation and found that the static capacity was reduced and the transmission correspondingly improved, which Mr. T. D. Lockwood found to be due to the occluded air among the loosely twisted fibrous paper, and not to the paper as an insulating material.

Mr. John A. Barrett, of New York, was intimately engaged upon experimentation and manufacture of cables, and to him are due many improvements in cable design.

At this time Mr. W. R. Patterson, now of Chicago, was working along independent lines, and made a form of hydraulic press for drawing on the lead cable sheath, which is still in use as the standard method of manufacture, although many changes of detail in the conductors have been introduced, with the result of improving telephonic transmission to over five times that of the first cables using twisted pairs.

The drawing in of underground cables is like the traction of locomotives, an instance of the occurrence of the unexpected. They can be drawn through devious ducts, around turns and across manholes, to an extent which was not anticipated. The early cables were wound with steel wire twisted on a long pitch to carry the stress of drawing in the cable.

Experiments on one drawn through an irregular conduit showed that the pull was about 20 tons, but such severe treatment is now avoided as unnecessary.

The cables are usually drawn in by man-power, either direct or applied to hand winches, but of late mechanical power has been applied to this work. Automobiles have been used for this work, but a cheaper and more efficient means has been reached by a 7-horse-power gasoline engine on a platform wagon, which also carries a winch.

In advance of a cable, the ducts must be first traversed by a wire to draw the cable, and the forerunner of this wire is either a number of wood rods hooked together and pushed along as section by section is added, and when the length to the next manhole is completed a strong wire is attached to the last rod, and as the first rod is pushed into the next manhole it is inserted in the corresponding duct on the other side of the manhole and pushed and pulled along, or if it is at the end of the cable run, the rods are pulled along and disjointed section by section.

A fine wire is sometimes drawn through a duct by a conical piece of wood with a thin leather washer filling the duct, and forced ahead by the air pressure at the rear, which is exerted through the application of an air pump at the front end of the duct at the next manhole.

This piece of wood is termed the "mouse," and the name is probably responsible for the persistent story that lines are first drawn through the conduits by a fine string tied to the tail of a tame rat who has been taught to do this work.

Cables are applied for miscellaneous other uses outside of conduits wherever the lines need protection against water, moisture or accidental violence. They are used for submarine lines at bridge draws and river crossings, where they appear to be the especial targets for fouling anchors and snarling propellers. The cables across the Mississippi at New Orleans become overlaid by the soft viscous mud of the river, which is so tenacious that it is impossible to pull them up again.

They are applied in tunnel work and in mining, and have even been led to a stranded steamship.

At Honolulu there are especial facilities for laying temporary cables to vessel anchored in the harbor, furnishing them with telephone service when in port.

In all United States seaports, vessels moored to wharves can promptly obtain temporary telephone service, for which wires already are placed upon the wharves ready to be extended to telephones to be installed in the cabin.

The subscribers are reached from underground cables by leading the cable through a pipe from the manhole, thence turning upward at the side of a pole, near the top of which the cables terminate in a cable box and the wires are separated into their several pairs, distributing to their respective instruments, generally by twisted pairs hung upon poles in rear alleys or attached close to buildings to avoid articles falling from windows or ice from roof cornices.

An entire underground system by which these laterals enter a basement, and thence by inside conductors extend through a building or perhaps an entire block is rare, except in the congested portion of large cities, where the number of patrons is sufficient to require the wires of a cable, and even then it is not always feasible to obtain permission from the several owners to make holes through division walls or to place in a building other wires than those used for the service of the occupants.

The modern office buildings are provided with channels in the walls for telephone wires, and also parallel grooves under the floors in multiples of 3 feet from the front side of rooms, so that wires can be run from the wire entrance of the building up through the floors to positions convenient to reach desk telephones, for as the telephone connections are made in less time than any other service, such as passenger elevators in buildings, or attention by salespeople in stores, so it takes too much time for the average business man to step to the telephone many times a day, and the electrical mountain must go to the commercial Mahomet, by placing the telephone on his desk.

These laterals and distributing pipes conveying the cables branching from the main system are sources of trouble in cold climates, for water penetrates them, usually by backing up from a flooded manhole, and by freezing in the space between the pipe and the cables, crush them until the insulation becomes impaired.

The former course required the expensive method of using a portable steam boiler, generally a city fire engine, to blow in steam from twelve to thirty-six hours to melt the ice, and then cut out the cable, which must be replaced by another one.

The Chicago Telephone Company equipped a wagon with step-down transformers and conductors, which could be attached to the electric light wires and furnish a current of 700 amperes at a low voltage.

The secondary wires from this wagon were attached by long clamps to the cable sheath at the distributing pole and at the manhole to furnish a current which warms the cable, and in a few minutes the melted ice runs into the manhole.

In some places, where there are not any electric lighting wires within an available distance, an automobile boiler is used to give a supply of steam, at far less cost than a steam fire engine, for which the hire is $5 an hour.

The cable is not disturbed, as it has been found that, although the ice pressure may have collapsed the cable to an extent sufficient to short circuit the conductors, yet the elasticity of the paper insulation is such that in a short time the insulation will be restored.

The damage by freezing does not take place in the horizontal pottery laterals of 3-inch sewer pipe leading from the manholes, but occurs in the iron pipe which comes down the side of the distributing pole and connects to this pottery pipe by an elbow of 3 feet radius and a straight run of 12 feet to the sewer pipe. It is proposed in the future to use sewer pipe runs and elbows.

Although lead-covered underground cables entering buildings or kept in storage are frequently gnawed by rats, who receive a swift retribution in case of cables containing high-tension circuits, yet aërial cables have of late received the attacks of insects which cut through the lead sheaths with their sharp mandibles for the purpose of laying eggs in the interior.

In China and Japan such perforations occur near the bamboo thickets, where an insect which lays its eggs in the bamboo stalks abounds.

This difficulty is met by wrapping such cables with burlap soaked in linseed oil.

In Australia similar difficulties have occurred over a wide expanse of territory, where it has been found that four species of beetles have in this manner perforated lead cable sheaths.

In Texas perforations are quite frequent, but it has not been found what insect produces these holes.

THE RATE OF TELEPHONE DEVELOPMENT.

It has been the endeavor to submit, as far as facilities for illustration provide, some of the obstacles presented by natural conditions to the construction and maintenance of telephone lines, in order to secure an appreciation of the engineering skill which has overcome these obstacles to the extension of telephone service which now knits together in one system over 26,000 different settlements throughout this country.

The establishment of this vast plant from small beginnings was attended for some years with a rate of increase which may appear slow in the light of later events, until the full development of long line service unified the whole into one connecting system, the value of whose service is far in excess of what could have been derived from isolated plants in separated towns.

These wider facilities endowed the telephone service with a higher value whose worth was appreciated, and the installation of telephones became stimulated to such a degree as to tax the resources of the various departments engaged on the work.

During the last five years the number of telephones in the system has increased at over three times the rate during the fifteen preceding years. This increase has been building upon itself like compound interest at the usurious rate of 29 per cent. a year, and compounding each year at this rate would double the number in 2¾ years, or the number of telephones has actually increased over 3½ times during the last five years.

Each of these instruments, as soon as installed, comes into full service for connection with other instruments, and thus reciprocally each new telephone adds to the availability and therefore the value of those with which it may be in communication.

During this last five years these additions of 29 per cent. a year have required corresponding amounts for the enormous increase in construction of new plant, which is entirely separate from the maintenance and repairs of the existing property.

> Truly the fabric of mental fleece,
> Resembles a weaver's masterpiece,
> Where a thousand threads one treadle throws,
> Where fly the shuttles hither and thither,
> Unseen the threads are knit together,
> And an infinite combination grows.
>
> GOETHE—FAUST, Sc. IV.

DISCUSSION.

MR. W. C. L. EGLIN.—The section is to be congratulated in having this subject of "Telephone Line Engineering" so ably and beautifully presented this evening. To-day the telephone is no longer looked upon as a luxury but as an everyday necessity. It fills a most important function in the business and social life of not only the cities, but also the suburban and country sections, and it may be looked upon as a necessity on account of the large percentage of the population of the United States which uses the telephone daily. Mr. Woodbury's very broad field has carried us over a wide and extended range of country, from the extreme south, up the "eastern shore" and across the continent to the Pacific Coast. From the illustrations seen it would appear that the principal difficulties to be overcome in telephone line engineering are more mechanical than electrical. Evidently the early constructors were misled, and had in mind putting the wires as high in the air as possible, with the intention, first, of having them as unsightly as possible, and, second, in getting them above the limbs and branches of the trees; overlooking the fact that the trees continued to grow, and it was only a matter of a few years before some of the branches would come in contact with the wires; and, further, that the higher the pole line the weaker the mechanical construction. For example, the illustration of the pole line in the city of New York, which fortunately has now been removed, carried over 200 wires which towered above the surrounding buildings. The unsightliness and danger of this great mass of wires in the city thoroughfare is forcibly impressed upon you by the illustration. A single cable, or a pair, supported on short poles would have carried all of the conductors in a much more satisfactory and, certainly, in a more permanent and substantial manner than the method used.

The other illustration of large poles were common a few years ago, viz., the distributing poles to which usually an underground cable was attached and the individual lines were run to the subscribers' premises. These poles were mostly unsightly, and in the case of a number of services, when placed in small streets, the wires would spread out like an umbrella over the entire area. This brings out one of the most important considerations, viz., the objections on the part of the property owner or the subscriber to having attachments made to his premises. The citizen frequently complains of the unsightliness of overhead construction, but offers no assistance in the abatement or lessening of the evil. The civic duty of citizens and property owners should prompt them to co-operate and assist the supply companies in maintaining the necessary service-wires in the least objectionable manner. Fortunately, these objections are being removed on account of the greater number of subscribers and the greater familiarity of the public with this class of construction. It can readily be appreciated that these lines could be carried more safely at the rear of the houses, and this would entirely remove the objection of unsightly appearances of distributing poles and wires.

From the illustrations of underground construction we see again that careful mechanical construction is of the first importance. Cables should not only be installed in proper conduits, but in the manholes they should also be properly arranged and carefully installed.

I am sure we all feel indebted to Mr. Woodbury for this most interesting lecture.

Stated Meeting, held Thursday, December 8, 1904.

An Amperemeter for High Potential Currents.

By H. Clyde Snook.

The instrument described is an ammeter for measuring currents flowing in the secondary circuits of induction coils.

A D'Arsonval system is used, modified by placing a small condenser in parallel with the moving coil and its calibration shunt to compensate for the high rate change of current, and by a ground on one side of the system to prevent sparking between the meter parts.

The instrument is especially adapted for use in X-ray work, because it was found that the quantity of X-rays was directly proportional to the current flowing in the tube.—The Editor.

This instrument has been devised expressly for measuring direct currents of a very high voltage. The immediate cause for its existence is the desire on the part of radiographers and physicians to know the capacity of the output of their induction coils and static machines.

Some work bearing directly on this line of investigation has been done by several workers recently. Gaiffè, a Frenchman, has produced a meter of the hot-wire type for measuring the secondary current of an induction coil, and Professor Sheldon, of the Brooklyn Polytechnic Institute, has conducted a series of investigations upon the static machine.

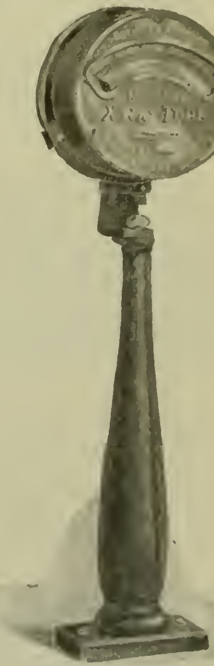


Fig. 1.

The interest in the matter is not a little, since it concerns the measurement of the dosage in X-ray treatment for therapeutic purposes, and the comparison of currents in Roentgen tubes used for making radiographs.

An induction coil does not deliver a secondary current of steady volume and practically unvarying potential; in fact, quite the contrary. The current and potential vary within wide limits, and the rate change of both is exceedingly high. During one complete cycle of magnetization and demagnetization of the core of an induction coil, we have a current curve in the primary about as shown in *Fig. 2.*

(It is assumed here that the induction coil is being operated by some form of the mechanical make-and-break contact shunted by a condenser.)

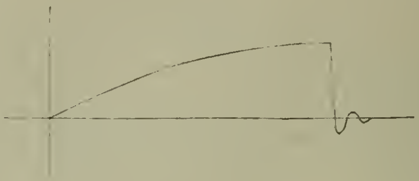


FIG. 2.

It is readily seen that the self-induction in the primary circuit prevents the current from rising suddenly after the contact is made, but that there is a very abrupt fall at break, followed by a slight oscillation due to the condenser. In connection with this curve it is assumed that the self-induction alone is used to limit the maximum current value.

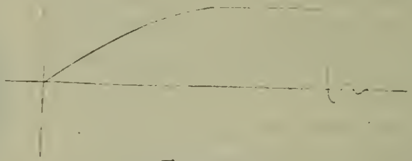


FIG. 3.

Should a higher voltage be used than the self-induction is capable of caring for, and a rheostat be used to control the current, the curve may assume various shapes, depending upon the amount of self-induction and rheostat resistance in the circuit (*Fig. 3*).

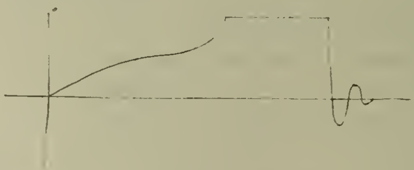


FIG. 4.

A curve something like this is obtained when there is a large enough resistance in the circuit that the rise of current is limited by the ohmic resistance, and not by the self-induction of the primary (*Fig. 4*).

This curve indicates too small a value of self-induction to prevent a rapid rise of current during part of the time of "make."

The current curve in the secondary circuit of the induction coil would be as follows if we assume a current curve in the primary, as in *Fig. 5.*

It should be remembered that the frequency of these cycles is usually something over 25 a second. The range of frequency of interruption of mechanical interrupters of different makes is from about 25 a second to about 300 a second.

Referring to curve (*Fig. 5*) of the secondary current, there is noted a long part of the wave induced in the secondary during the time of contact, that is, during the time of the rise of the current in the primary.

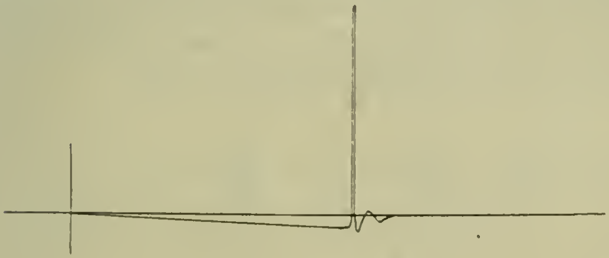


FIG. 5.

This part of the curve, together with the other small wave at the end of the curve, has been dubbed the "inverse discharge," as it is of opposite E.M.F. to that of the part of the curve corresponding to the long spark and the "break" of the interrupter.

It is an "inverse discharge" because it is in inverse direction to the direct or long spark of the coil, and is very small in coils which depend upon the self-induction of the primary coil to control the current value in the primary circuit. In coils which are operated upon 100 or 220 volts, primary current rheostatic control is used, and there is apt to occur either a condition found in curve (3), where there is a large loss of energy in the rheostat, or a high rate change of current rise as in curve (4), which is productive of the "inverse discharge." This need of a means of controlling the primary current by means of the self-induction is very nicely provided for in coils operating upon low voltages, as obtained from batteries, by the use of a value of self-induction high enough that the current can be controlled entirely by altering the length of time during which current is permitted to flow in the primary circuit, that is, the length of "make."

The obvious cure for the rheostatic loss and for the presence of the "inverse discharge" is a means for varying the self-induction of the primary circuit to suit the current used in it.

It is of great concern to the Roentgenologist to dispense with the "inverse discharge," because it does not produce usable X-rays, and because when it is present in his tube it does two things which tend to impair his tube:

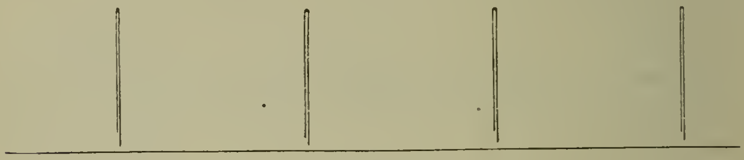


FIG. 6.

(1) When it is passing through the tube the platinum anode temporarily becomes a cathode, platinum is carried off by the cathode streams and plated on the inner walls of the glass tube, rendering them more opaque to the passage of the Roentgen rays and presenting a very large absorption surface whereby the gas of the tube is rapidly occluded and the vacuum raised beyond a point where it is manageable.

(2) When the anode becomes a cathode the occluded gas which it holds is very rapidly given up to the gas of the tube vacuum and a sudden lowering of the vacuum is apt to occur, especially with new tubes. The practical result is that when the inverse discharge is allowed to enter the tube it does not produce usable X-rays, and it causes a temporary lowering but a subsequent permanent raising of the vacuum of the tube.

Though it is a part of the output of the induction coil, the inverse discharge is not usable in a Roentgen tube and is not measured by the instrument we are discussing. The current which the X-ray man uses in his tube is a number of disconnected unidirectional impulses separated by intervals long in time when compared with the length of their own individual duration (*Fig. 6*).

CURVES OF CURRENT IN A ROENTGEN TUBE.

This instrument is a D'Arsonval system adapted to integrate the waves of current above shown and give a continuous reading of the same.

The frequency of the occurrence of the waves is in every instance far beyond the natural period of the moving system which is damped in the usual manner by having the moving coil wound on a conducting frame.

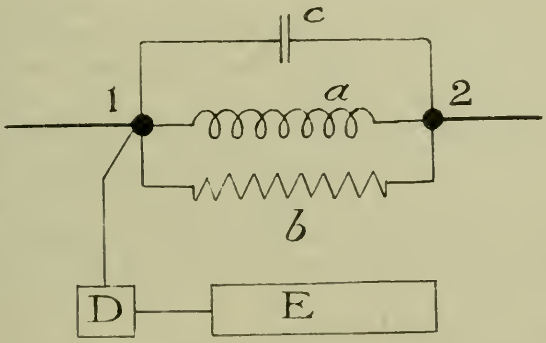


FIG. 7.

Diagrammatically the instrument (*Fig. 7*) is as follows: *1* and *2* are the binding posts; *a* is the moving coil; *b* is the calibration non-inductive shunt; *D* is the permanent magnet with its core; *E* is the iron case of the instrument and *c* is the small mica condenser.

D is seen to be connected to the post *1*, and *E* is connected to *D*.

The entire instrument is mounted upon an insulating pillar; and the case, magnet and core, with the moving system and shunt coil are all connected together so that they may rise and fall in potential together, in unison with the varying potential of the secondary circuit.

It is readily seen that the only difference of potential between the meter parts is thus made to be merely the drop through the two coils.

The question of high insulation to withstand high potentials is thus prevented from being raised, and the only insulation employed is that ordinarily used in direct-current measuring instruments.

Due to the very high rate change of current, the self-induction of the moving coil would prevent its taking its full proportion of the current. It was found in practice that the E.M.F. induced between turns was high enough to produce internal sparking in the moving coil and sparking from the coil to its metal frame.

The rate change of current rise and fall does not depend upon the frequency of interruption but upon the rate with which the core loses its magnetic field. This is influenced largely by the eddy current losses in the core of the primary. Eddy current losses are inappreciable in induction coil cores laminated as they are by being constructed of small iron wires. The residual effect is practically a constant quantity in the open cores, so that we are dealing with a fairly constant rate change of flux and a correspondingly constant rate change of induced current.

At *c* we have the condenser, which acts as a hold-over device, as a condenser to take up the surges of current and deliver them more steadily to the moving coil. In this manner the effect of the self-induction of the moving coil is neutralized and the drop in potential between the meter posts more nearly approximates the ohmic fall of potential of the two coils.

As a matter of course, if the "inverse discharge" is permitted to pass through the meter, the meter reading will be the algebraic sum of the integrated values of the direct and inverse currents. This will result in a reading less than the correct value of the direct discharge.

Several methods are used to prevent the passage of the "inverse discharge," and it is usually accomplished by inserting a series spark-gap or a valve tube or both in the secondary circuit in series with the X-ray tube. As previously mentioned, a preventive measure is the use of a high value of self-induction in the primary circuit.

The currents obtained from static machines are quite steady direct currents when oscillations are not set up in leyden jar or other capacity circuits connected with them, and this instrument is naturally adapted to the measurement of the currents delivered by such machines.

Decidely interesting results are obtained from comparisons of readings of the currents taken by Roentgen tubes on different types of coils.

A soft tube takes much more current than a hard tube even when both are operated on the same coil without having made any change in the coil adjustments. In fact, the same tube when hard takes much less current than when it is soft. If a tube drops in vacuum during use, the fact is announced by the needle of the meter moving upward on the scale, thus indicating more current. And if, on the contrary, the tube rises in vacuum during its use, the needle falls back, indicating less current.

If the inverse discharge begins to pass into the tube, the meter-needle will begin to retreat rapidly, and will give a much lower reading as the volume of the coil discharge is increased.

An X-ray tube having an initial resistance of 3 inches parallel spark resistance will take much less current than a spark gap of 3 inches of air. That is, the change in resistance of the X-ray tube when it takes current is much less than the change in resistance of a spark gap in air, which has the same initial resistance as that of the tube.

For instance, a coil may be adjusted to push 1 milliampere through a tube of 3 inches parallel spark resistance. If the tube be removed and a spark gap of 3 inches in air be made in its stead, 6 or 8 milliamperes will flow across the spark gap without any change in the adjustment of the coil. Ionisation must play a large part in the striking difference found in the degree of the change of resistance.

The current obtainable from an induction coil when sparking in air varies anywhere from zero to 50 milliamperes, depending upon the length of the spark in the air, the size of the coil, the efficiency of the coil, the resistance of the secondary and the manner in which the coil is operated.

The maximum current which I have been able to obtain from a static machine was $\frac{8}{10}$ of a milliampere. This reading was taken from a large machine having 12 revolving glass plates.

Different induction coils of varying sizes and capacities will deliver to X-ray tubes of varying vacuums currents up to about 14 milliamperes as a maximum.

Standardization of and measurement of X-ray dosage is made possible by the use of this instrument; for the quantity of the X-rays is proportional to the current in the tube.

A comparison of the currents taken by many tubes of different makes and of varying parallel spark resistance has shown that there is scarcely any noticeable difference in the efficiencies of tubes of different makes when they are operated at the same vacuum and with the same number of milliamperes of current.

As a tube grows older and the absorption layer of metallic deposit increases in thickness where deposited on the walls of the tube, its efficiency in radiating X rays for a given current is somewhat lessened. But any given tube at a stated degree of vacuum gives off X rays in direct proportion to the current which flows through the tube in the proper direction.

We thus have a means of measuring the quantity of X-rays.

It follows that it makes no difference whether the various X-ray workers have static machines or coils, or whether some of them have mercury jet, or electrolytic or other kinds of interrupters, if each worker will record the distance of the anticathode of the tube from the part exposed, the time of exposure, the degree of vacuum of the tube, and the number of milliamperes of current flowing in the tube, his conditions are definitely known and can be duplicated by any other worker.

I wish to state that Messrs. G. Herbert White and Edwin W. Kelly, of the Roentgen Manufacturing Company, have rendered me great assistance in the experiments relating to this instrument.

Determination of Exponents of Adiabatics.

By Thomas M. Gardner,
Member of the Institute.

A paper showing that no simple relationship exists between the values of adiabatic exponents and specific, latent or total heats. Algebraic and graphical methods of determination are used. Tables of average and instantaneous values of n, with their corresponding sheets of curves, are given for steam, carbon disulphide, ether, carbon tetrachloride and acetone. Surfaces having instantaneous exponent, pressure and quality values on coordinate axes are shown.—The Editor.

It was found by Rankine that the law of adiabatic expansion of steam was approximately represented by $pv^n = c$, and gave 10/9 as the value of n. A series of pressures with their corresponding volumes were chosen, and the final pressures with their volumes obtained. These values were inserted in the formula:

$$p_1 v_1^n = p_2 v_2^n,$$

or

$$n = (\log. p_1 - \log. p_2) \div (\log. v_2 - \log. v_1).$$

The several results were averaged, and the number given above for steam was obtained. This value of n is only an average exponent; if from $pv^n = c$ the curve be drawn, it will intersect the ideal expansion line in two points, and will differ at all others.

As the exponent varies for different ranges of expansion on the adiabatic, it is desirable that the instantaneous values of n for a number of equal intervals of pressure be determined. Since

$$pv^n = c$$

$$\log. p = n \log. v$$

$$dp / p = n\, dv / v$$

whence

$$dp / dv \div p / v = n.$$

Method of obtaining the slope dp/dv:

p	v	Δv	$\Delta_2 v$	$\Delta_3 v$
p_1	v_1			
		a_1		
p_2	v_2		b_1	
		a_2		c_1
p_3	v_3		b_2	
		a_3		c_2
p_4	v_4		b_3	
		a_4		c_3
p_5	v_5		b_4	
		a_5		c_4
p_6	v_6		b_5	
		a_6		
p_7	v_7			

Suppose it is desired to find dv/dp at p_4. Beginning at v_4, the first, second and third differences are a_3, b_2 and c_1 along the line with an upward trend to the right, and in the downward direction are respectively a_4, b_4 and c_4. Let the differences between p_7 and p_6, p_6 and p_5, etc., be denoted by m, then

$$m\,dv/dp = a_3 + 1/2\,(b_2) + 1/3\,(c_1)$$

and

$$a_4 - 1/2\,(b_4) + 1/3\,(c_4),$$

both series being continued till an order of differences is reached that vanishes. Then

$$2\,m\,dv/dp = (a_3 + a_4) - 1/2\,(b_4 - b_2) - 1/3\,(c_4 + c_1),$$

etc. The first, second and third approximations are the first quantity—the first two and the first three.

The proper second approximation is:

$$2\,m\,dv/dp = (a_3 + a_4) - 1/6\,(b_4 - b_2).$$

This would be exact if v were expressed by equation:

$$v = ap + bp^2 + cp^3 + dp^4.$$

The second equation above is obtained by using Taylor's formula:

$$u_x = u_0 + xa_0 + \frac{x^2}{2}\,b_0 + \frac{x\,(x^2 - 1)}{3}\,c_0 + \frac{x^2\,(x^2 - 1)}{4}\,d_0,$$

differentiating with regard to x and putting $x = 0$:

$$du/dx_0 = a_0 - 1/6\,c_0 + 1/30\,e_0, \text{ etc.}$$

Since only two differences can be obtained that are sufficiently accurate for use, it is not worth while to consider

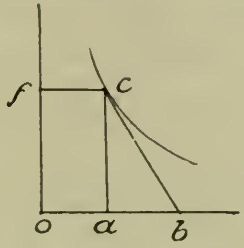


FIG 1.

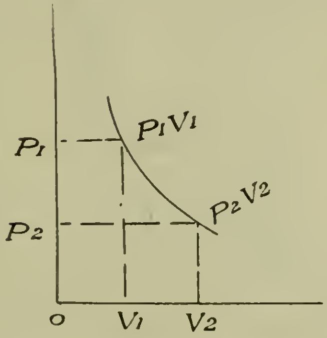


FIG. 2.

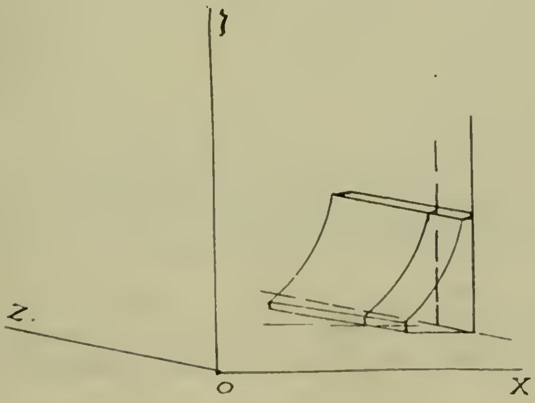


FIG. 3.

the third approximation. So, if from the adiabatics, *Figs. 4, 5, 6* and *7*, a table be constructed of pressures, volumes, first and second differences, the values of dv / dp may be obtained. Taking the reciprocal of dv / dp and substituting in the formula $dp / dv \div p / v = n$, the instantaneous values of the exponent may be found.

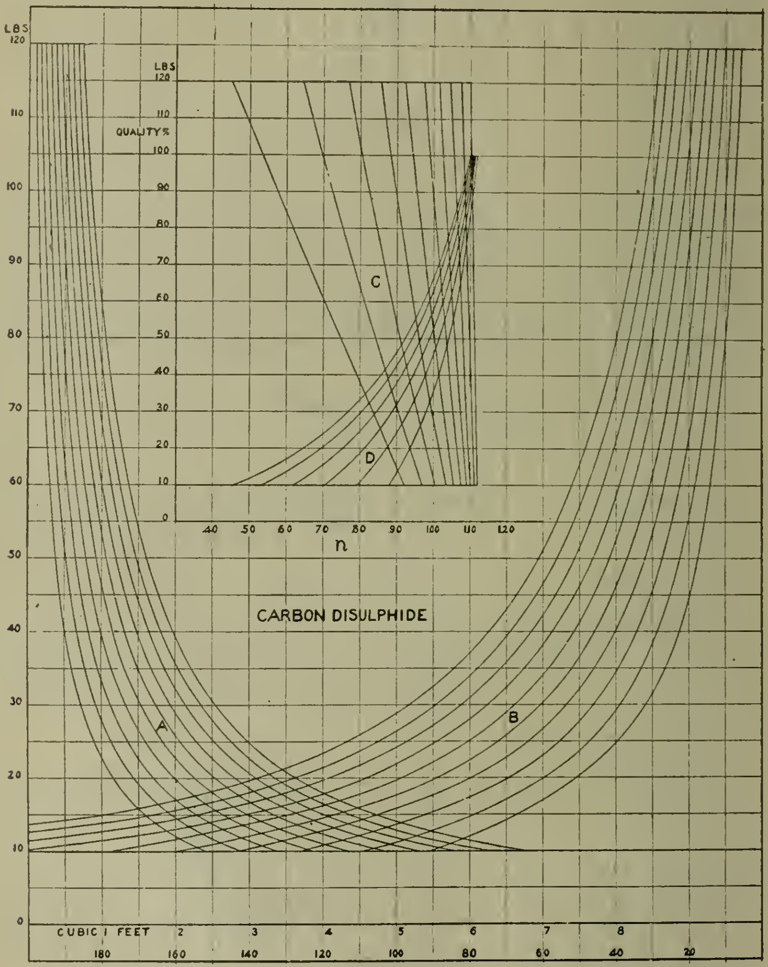


FIG. 4.

Graphical Methods.—In *Fig. 1* let *c* be the point on the adiabatic for which the exponent is desired. Take value *cf* (= *oa*). Place a straight edge tangent at *c*, and read *ob*, then $oa \div (ob - ab) = n$; for since

$$n = dy/dx \div y/x = ca/ab \div ca/oa = oa/ab = n.$$

NOTE.—Even with extreme care in drawing tangent *cb* the error in the value of *n* may be as much as 10 per cent.

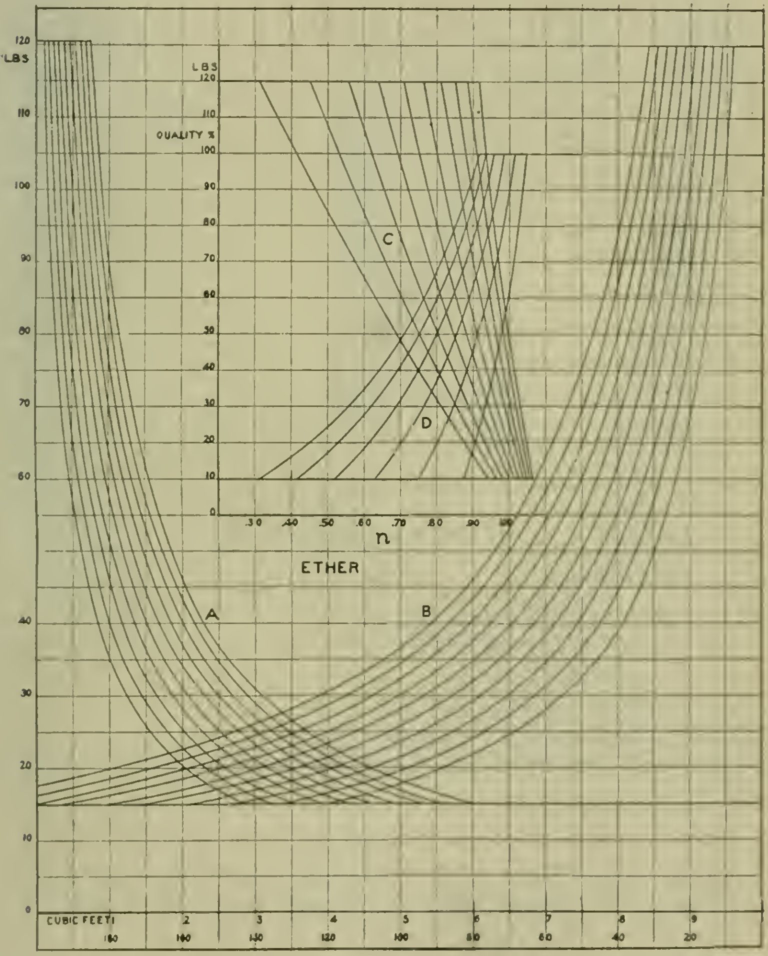


FIG. 5.

To obtain an average value of n.—Fig. 2—On the Y axis of logarithmic cross-section paper lay off of p_1 and p_2 from O. On the X axis do likewise for v_1 and v_2. On either axis lay off $p_1 - p_2$ and and $v_2 - v_1$ from O. Take difference $(p_1 - p_2)$ -

(v_2 v_1) with a pair of compasses and determine the exponent by measuring from *O* and reading the number corresponding.

It has just been stated that Rankine's value of *n* for adiabatic expansion of steam was 10/9, or 1·11. This was

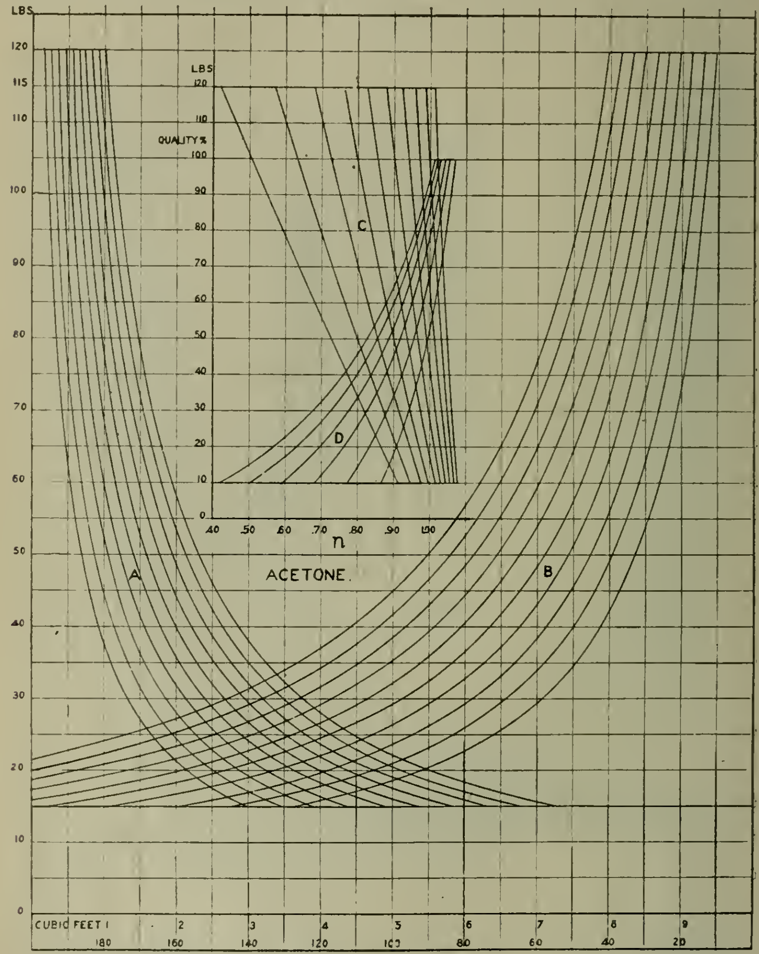


Fig. 6.

later pointed out by Grashof to be too small, but was true for initial dryness fraction of between 75 and 80 per cent. 76 per cent., that is, for a definite mixture of steam and water, and that for expansion from an initial state of perfect dryness, $n = 1.14$.

Zeuner made calculations, using initial pressures of 4, 2 and 1 atmospheres, and final pressures of 2, 1 and 5/10, 1 and 5/10, and 5/10 atmospheres, obtaining the following exponents:

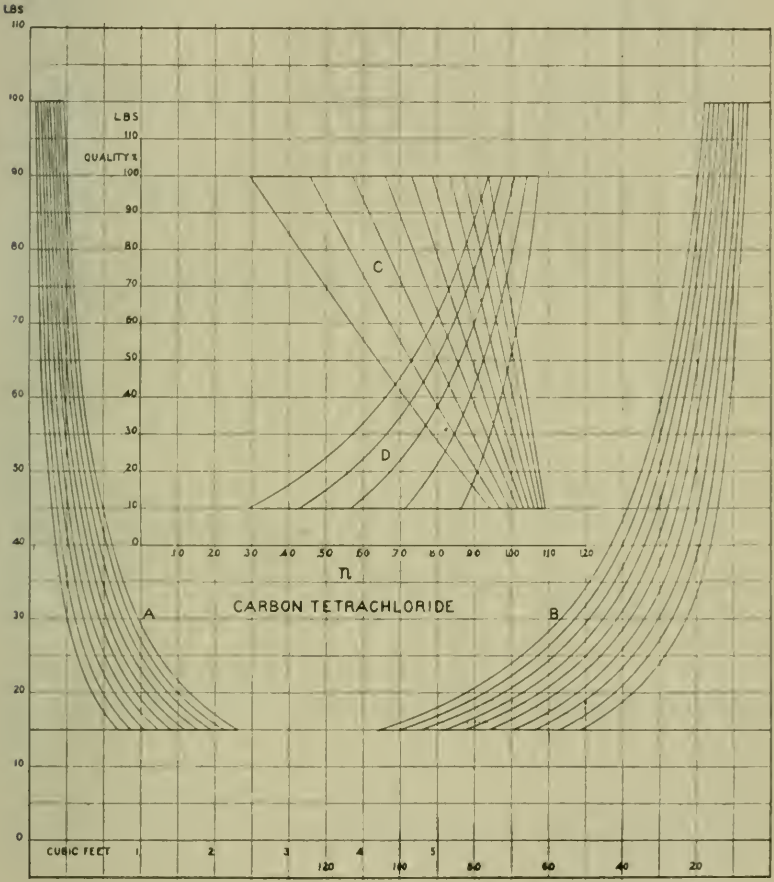


FIG. 7.

$x = 100$ per cent. $n = 1{\cdot}135$

$x = 90$ " $n = 1{\cdot}125$

$x = 80$ " $n = 1{\cdot}115$

$x = 70$ " $n = 1{\cdot}103$

and finds that for adiabatic expansion of steam whose dryness fraction is between 100 per cent. and 70 per cent., that the value of the exponent is fairly represented by

$$n = 1{\cdot}035 + x/10.$$

STEAM.

Exponents for Adiabatic Expansion. Average Values of "n" for Initial Qualities of

Temperature Range, Deg. F.	Pressure Range, Lbs. Abs.	100 Per Cent.	90 Per Cent.	80 Per Cent.	70 Per Cent.	60 Per Cent.	50 Per Cent.	40 Per Cent.	30 Per Cent.	20 Per Cent.	10 Per Cent.
341 to 228	119·9 to 20·	1·1397	1·1301	1·1185	1·1043	1·0863	1·0630	1·0311	·9854	·91315	·78296
293 " 194	60·45 " 10·2	1·1366	1·1273	1·1175	1·1052	1·0896	1·0691	1·0409	·9995	·93275	·80450
250 " 162	29·86 " 4·96	1·1309	1·1238	1·1151	1·1043	1·0905	1·0723	1·0469	1·0092	·94704	·82378
213 " 135	14·99 " 2·53	1·1291	1·1229	1·1152	1·1057	1·0934	1·0771	1·0542	1·0196	·96170	·84282
Average . .		1·1341	1·126	1·1166	1·1049	1·09	1·0704	1·0433	1·0034	·93866	·81352

Instantaneous Values of "n" for Initial Qualities of

Pressures, Lbs. Abs.	100 Per Cent.	90 Per Cent.	80 Per Cent.	70 Per Cent.	60 Per Cent.	50 Per Cent.	40 Per Cent.	30 Per Cent.	20 Per Cent.	10 Per Cent.
110	1·164	1·151	1·1135	1·117	1·096	1·065	1·019	·958	·854	·657
100	1·159	1·147	1·132	1·113	1·092	1·062	1·019	·960	·864	·680
90	1·153	1·142	1·128	1·110	1·090	1·060	1·019	·965	·874	·703
80	1·149	1·138	1·125	1·107	1·088	1·059	1·021	·970	·884	·728
70	1·145	1·135	1·123	1·105	1·088	1·060	1·025	·976	·897	·754
60	1·141	1·132	1·120	1·104	1·086	1·061	1·030	·983	·908	·783
50	1·138	1·130	1·118	1·103	1·086	1·063	1·035	·990	·921	·807
40	1·134	1·126	1·114	1·102	1·086	1·064	1·039	·998	·936	·836
30	1·130	1·122	1·111	1·100	1·085	1·065	1·042	1·009	·952	·867
20	1·125	1·116	1·107	1·097	1·084	1·067	1·045	1·020	·970	·879

The exponent n is practically constant in the 60 per cent. column.

CARBON DISULPHIDE.

Exponents for Adiabatic Expansion. Average Values of "n" for Initial Qualities of

Temperature Range, Deg. F.	Pressure Range, Lbs. Abs.	100 Per Cent.	90 Per Cent.	80 Per Cent.	70 Per Cent.	60 Per Cent.	50 Per Cent.	40 Per Cent.	30 Per Cent.	20 Per Cent.	10 Per Cent.
265 to 135	120·3 to 20·7	1·1127	1·0963	1·0770	1·0542	1·0262	·9922	·9488	·8913	·7338	·6889
205 " 95	58·55 " 10·4	1·1268	1,1131	1·0969	1·0778	1·0554	1·0217	·9916	·9273	·8278	·7166
160 " 60	30·96 " 4·82	1·1294	1·1179	1·1042	1·0912	1·0600	1·0399	1·0042	·9542	·8482	·7476
115 " 32	14·57 " 2·47	1·1344	1·1246	1·1129	1·0984	1·0802	1·0564	1·0242	·9779	·9052	·7727

Instantaneous Values of "n" for Initial Qualities of

Pressures, Lbs. Abs.	100 Per Cent.	90 Per Cent.	80 Per Cent.	70 Per Cent.	60 Per Cent.	50 Per Cent.	40 Per Cent.	30 Per Cent.	20 Per Cent.	10 Per Cent.
120	1·100	1·075	1·044	1·014	·9750	·922	·857	·769	·646	·453
110	1·101	1·078	1·049	1·020	·9815	·933	·870	·789	·670	·494
100	1·102	1·082	1·053	1·024	·9890	·943	·883	·804	·697	·536
90	1·105	1·085	1·060	1·030	·9970	·954	·893	·825	·725	·577
80	1·107	1·089	1·066	1·037	1·007	·966	·913	·845	·753	·620
70	1·109	1·093	1·070	1·043	1·017	·978	·929	·866	·782	·660
60	1·110	1·096	1·077	1·050	1·026	·990	·945	·888	·813	·705
50	1·112	1·098	1·080	1·058	1·034	1·003	·961	·910	·843	·750
45	1·113	1·100	1·082	1·062	1·039	1·009	·970	·921	·859	·770
40	1·114	1·101	1·084	1·065	1·043	1·015	·978	·933	·874	794
35	1·115	1·103	1·087	1·070	1·048	1·021	·988	·945	·890	·815
30	1·116	1·106	1·090	1·073	1·053	1·028	·997	·956	·905	·836
25	1·117	1·107	1·092	1·078	1·059	1·034	1·006	·968	·922	·858
20	1·118	1·110	1·095	1·081	1·063	1·041	1·015	·980	·937	·880

ETHER.

Exponents for Adiabatic Expansion. Average Value for "n" for Initial Quatities of

Temperature Range, Deg. F.	Pressure Range, Lbs. Abs.	100 Per Cent.	90 Per Cent.	80 Per Cent.	70 Per Cent.	60 Per Cent.	50 Per Cent.	40 Per Cent.	30 Per Cent.	20 Per Cent.	10 Per Cent.
230 to 110	120·31 to 19·6	·9911	·9715	·9491	·9236	·8938	·8536	·8163	·7640	·6971	·6048
180 " 80	61·9 " 10·8	1·0170	·9987	·9775	·9528	·9236	·8884	·8448	·7892	·7150	·6069
135 " 55	30·62 " 6·23	1·0359	1·0193	·9997	·9764	·9483	·9137	·8699	·8125	·7329	·6113
95 " 32	14·72 " 3·54	1·0504	1·0352	1·0172	·9957	·9693	·9362	·8940	·8356	·7527	·6202

Instantaneous Values of "n" for Initial Qualities of

Pressures, Lbs. Abs.	100 Per Cent.	90 Per Cent.	80 Per Cent.	70 Per Cent.	60 Per Cent.	50 Per Cent.	40 Per Cent.	30 Per Cent.	20 Per Cent.	10 Per Cent.
120	·917	·885	·852	·812	·764	·710	·640	·557	·450	·312
110	·925	·897	·866	·828	·781	·730	·665	·558	·490	·362
100	·934	·910	·880	·848	·800	·752	·693	·620	·530	·414
90	·945	·923	·896	·862	·820	·775	·721	·653	·592	·465
80	·956	·937	·912	·881	·842	·800	·750	·689	·614	·520
70	·970	·952	·928	·900	·864	·826	·780	·725	·658	·575
60	·984	·968	·946	·920	·887	·853	·813	·763	·704	·631
50	·998	·984	·964	·941	·913	·882	·847	·803	·751	·690
40	1·014	1·000	·984	·964	·939	·920	·882	·845	·801	·750
30	1·031	1·018	1·003	·987	·966	·959	·920	·888	·853	·810
20	1·047	1·037	1·024	1·012	·995	·980	·959	·933	·907	·875
10	1·065	1·047	1·037	1·024	1·010		·980	·957	·935	·941

ACETONE.

Exponents for Adiabatic Expansion. Average Values of "n" for Initial Qualities of

Temperature Range, Deg. F.	Pressure Range, Lbs. Abs.	100 Per Cent.	90 Per Cent.	80 Per Cent.	70 Per Cent.	60 Per Cent	50 Per Cent	40 Per Cent.	30 Per Cent.	20 Per Cent.	10 Per Cent.
284 to 158	135·5 to 23·04	1·0413	1·0229	1·0000	·9767	·9473	·9118	·8679	·8120	·7376	·6309
230 " 122	69·5 " 11·77	1·0640	1·0479	1·0292	1·0068	·9797	·9463	·9040	·8482	·7705	·6500
176 " 86	31·2 " 5·42	—	—	—	—	—	—	—	—	—	—
140 " 50	16·6 " 2·69	1·1304	1·1182	1·1036	1·0859	1·0640	1·0640	·9993	·8483	·8723	·7431

Instantaneous Values of "n" for Initial Qualities of

Pressures, Lbs. Abs.	100 Per Cent.	90 Per Cent.	80 Per Cent.	70 Per Cent.	60 Per Cent.	50 Per Cent.	40 Per Cent.	30 Per Cent.	20 Per Cent.	10 Per Cent.
120	1·010	·982	·953	·912	·869	·813	·744	·657	·540	·378
110	1·016	·991	·963	·931	·889	·840	·780	·702	·600	·440
100	1·021	·997	·970	·940	·900	·854	·798	·725	·631	·504
90	1·026	1·002	·978	·950	·912	·870	·817	·750	·663	·547
80	1·030	1·010	·985	·960	·925	·885	·838	·777	·696	·597
70	1·037	1·016	·993	·970	·638	·902	·857	·801	·730	·637
60	1·042	1·023	1·003	·979	·950	·919	·877	·827	·763	·682
50	1·047	1·031	1·012	·990	·964	·937	·900	·856	·799	·727
40	1·053	1·039	1·022	1·002	·980	·954	·921	·884	·834	·772
35	1·058	1·043	1·028	1·009	·687	·963	·933	·900	·853	·796
30	1·061	1·048	1·033	1·016	·996	·973	·945	·915	·870	·818
25	1·064	1·052	1·039	1·022	1·004	·983	·958	·930	·890	·842
20	1·068	1·057	1·044	1·030	1·012	·993	·970	·945	·907	·865
15	1·083	1·062	1·050	1·036	1·020	1·003	·982	·960	·927	·888
10	1·087	1·067	1·056	1·043	1·030	1·013	·996	·975	·945	·912

CARBON TETRACHLORIDE.

Exponents for Adiabatic Expansion. Average Values of "n" for Initial Qualities of

Temperature Range, Deg. F.	Pressure Range, Lbs. Abs.	100 Per Cent.	90 Per Cent.	80 Per Cent.	70 Per Cent.	60 Per Cent.	50 Per Cent.	40 Per Cent.	30 Per Cent.	20 Per Cent.	10 Per Cent.
320 to 176	106·6 to 16·31	·9860	·9664	·9441	·9167	·8947	·8496	·8060	·7524	·6835	·5890
266 " 158	57·95 " 12·01	1·0498	1·0315	1·0100	·9740	·9550	·9183	·8724	·8129	·7320	·6114
176 " 86	16·31 " 2·751	1·0962	1·0822	1·0656	1·0455	1·021	·9898	·9494	·8944	·7977	·6839

Instantaneous Values of "n" for Initial Qualities of

Pressures, Lbs. Abs.	100 Per Cent.	90 Per Cent.	80 Per Cent.	70 Per Cent.	60 Per Cent.	50 Per Cent.	40 Per Cent.	30 Per Cent.	20 Per Cent.	10 Per Cent.
100	·9375	·906	·872	·834	·786	·730	·659	·571	·455	·293
90	·964	·930	·894	·859	·815	·763	·697	·616	·509	·360
80	·973	·946	·916	·883	·843	·795	·735	·660	·563	·428
70	·990	·966	·938	·907	·870	·827	·773	·707	·617	·496
60	1·007	·985	·960	·931	·897	·860	·813	·753	·673	·567
50	1·024	1·006	·981	·957	·926	·893	·852	·800	·729	·639
45	1·033	1.016	·993	·969	·940	·910	·873	·825	·758	·675
40	1·042	1·023	1·004	·982	·954	·923	·888	·846	·787	·711
35	1·050	1·035	1·015	·994	·969	·943	·913	·870	·816	·749
30	1·058	1·044	1·027	1·007	·984	·960	·933	·894	·845	·786
25	1·066	1·054	1·038	1·020	1·000	·979	·953	·920	·876	·825
20	1·074	1·063	1·049	1·033	1·015	·996	·973	·943	·907	·863
15	1·082	1·072	1·060	1·046	1·030	1·013	·995	·970	·938	·901
10	1·090	1·082	1·072	1·060	1·047	1·031	1·016	·994	·969	·940

The tabulated values of n, in the preceding, were computed from a well-known steam table with Vega's logarithms and are essentially the averages from 100 to 70 per cent., inclusive, as found by Zeuner. It is seen that as x decreases, n decreases. For 100, 90, and 80 per cent. qualities at the several pressures n decreases; for 60 per cent. and below it increases. At 70 per cent., n is practically constant. When the curves are plotted, as in *Fig. 9*, a crossing of each other is noticed. This cannot be said of carbon di-sulphide, acetone, ether, or carbon tetrachlorides. Ammonia and some of the other vapors have not been considered on account of lack of experimental data for specific heats of the liquids. Alcohol was omitted because of the fact that dissociation takes place during evaporation.

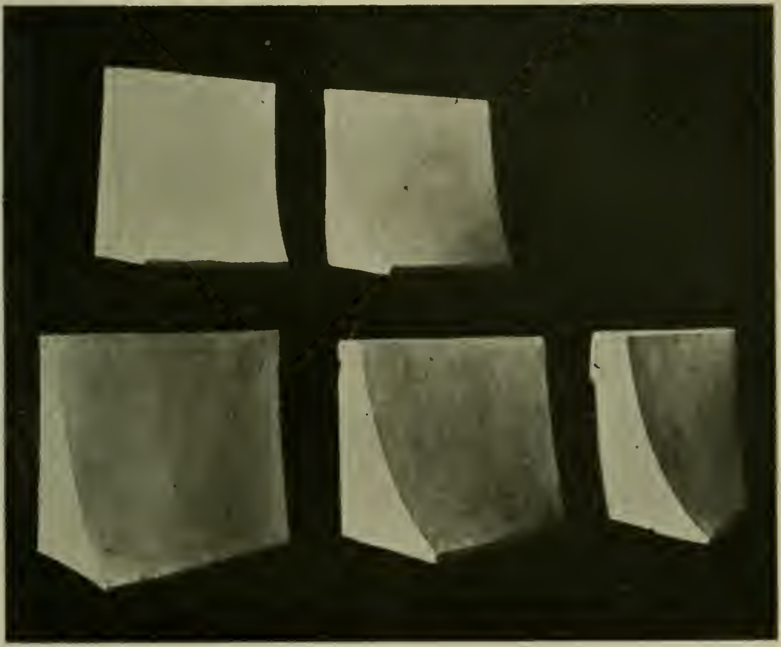


FIG. 8.

The hyperbola, which is used quite largely as a curve for comparison with the expansion curve on an indicator diagram, would not be traced by the indicator pencil, true

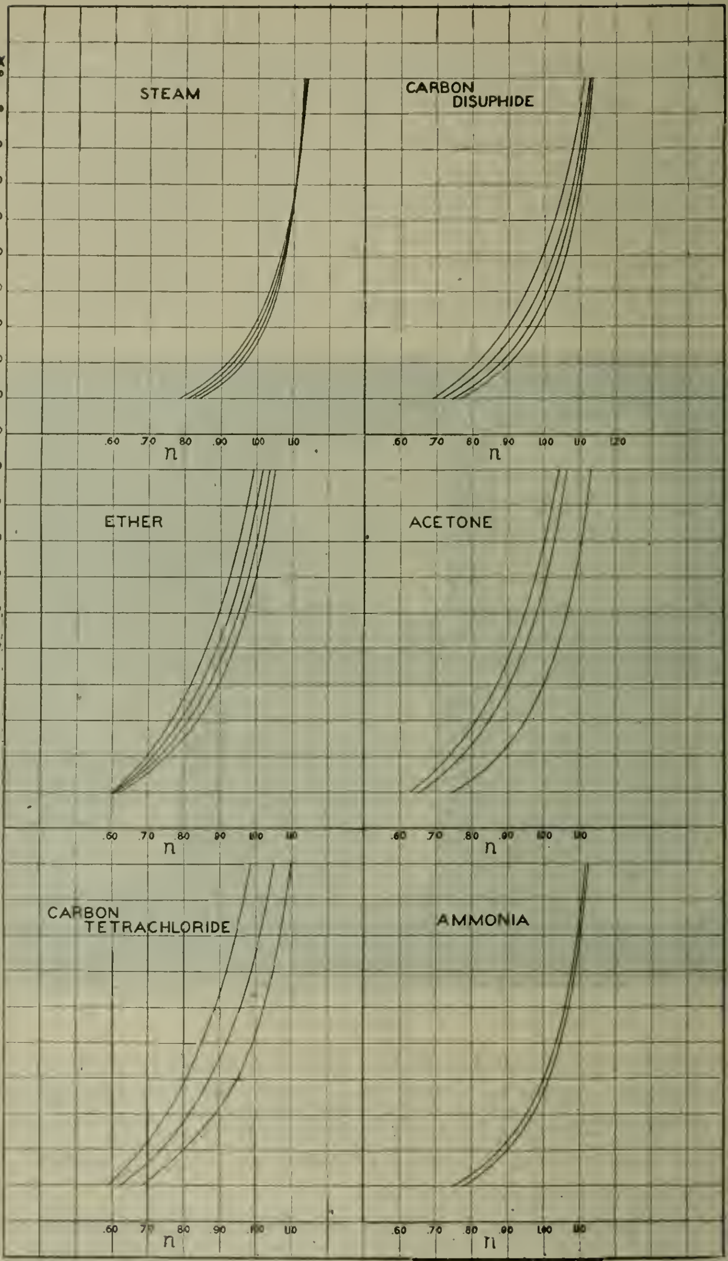

X
STEAM
CARBON DISUPHIDE
ETHER
ACETONE
CARBON TETRACHLORIDE
AMMONIA
100
.90
.80
.70
.60
.50
.40
.30
.20
.10
0
.60
.70
.80
.90
1.00
1.10
1.20
n

Fig. 9.

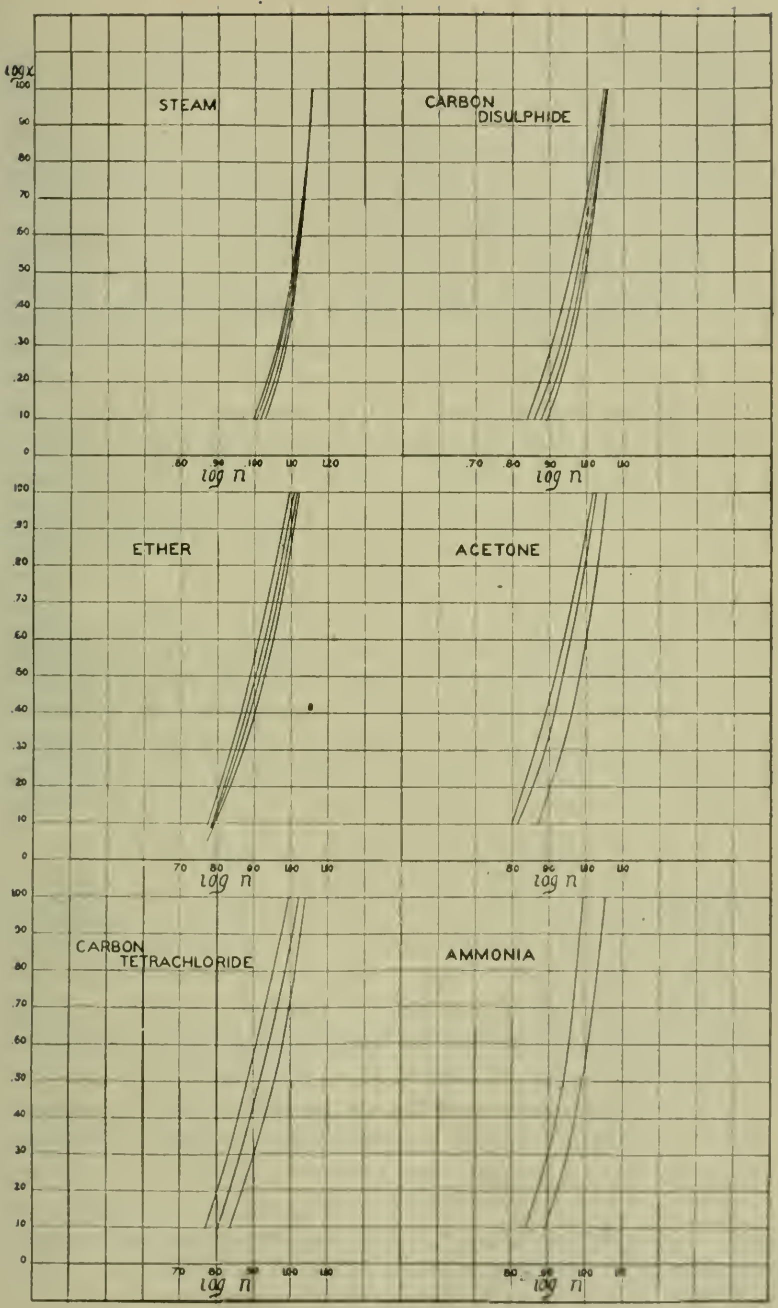


FIG. 10.—NOTE.—The characteristics of log *n* as plotted have been increased by unity.

adiabatic expansion taking place, until the quality was reduced to 31 or 32 per cent.; practically two-thirds of the weight of steam having condensed.

The lower parts of the preceding five tables give instantaneous values of n. The variation between these values and the average values above are quite noticeable.

In *Figs. 4, 5, 6* and *7*, the sets of large curves at the left are the adiabatics and those at the right, marked *B*, are their evolutes. Referring to the central diagrams, those curves which diverge upwards, *C*, give instantaneous exponent values for the different pressures along the several adiabatics, so marked from initial qualities. The other sets of curves, *D*, to the same axes, show the instantaneous values of n for any given pressure, across the several adiabatics. Since these diagrams have three sets of variables, solids may be formed which will give the instantaneous value of n for any given pressure and dryness fraction. The photograph, *Fig. 8*, is that of the five solids so obtained. Beginning at the top and reading to the right are those of steam, carbon disulphide, ether, acetone and carbon tetrachloride. Their similarity of figure is quite noticeable. If horizontal planes be passed through the surfaces, the lines of intersection are the curves *D* and *C* in the plates just described. Planes giving curves marked *D*, are those made by the *XY* planes passed through the surface, as shown in *Fig. 3*.

It was hoped that some general expression might be obtained which would give the exponents for adiabatic expansion for any vapor at any pressure with any given quality modification. It is seen that the curves *D*, *Figs. 4, 5, 6* and *7*, are not coincident, hence any expression that might be obtained would be too cumbersome to be of any practical use. *Fig. 9* shows that the average values of n do not form coincident curves. In the following *Fig. 10*, where their logarithmic values are plotted, it is seen that while the curves are not coincident they form almost straight lines to 60 per cent. quality; that is, any given curve representing the varying exponential values at a given pressure, is almost logarithmic. That being the case,

$$n. = (x / c)^a$$

If now an expression for the 100 per cent. initial quality line of *C*, of the preceding *Figs. 4, 5, 6* and *7*, be obtained, which would give the value *a* at any given pressure, then *n* for a limited range becomes known.

It may be further said, upon comparing exponents for any given temperature, or any given pressure for the several vapors, or for any given range of pressure of the several vapors, it was found that there was no direct relationship between those values of *n* and latent, total, or specific heats.

MAGNESITE AS A LINING FOR FIRE-BRICK.

Magnesite, calcined in an electric furnace, and used as a wash on the fire-bricks lining a melting pot in a calcium-carbide furnace, stood the heat for 200 hours without repair, whereas the bricks that were unprotected required repair after a five hours' heat.

KUNZITE.

Kunzite, a variety of spodumene, found in California, is now cut and sold as a gem in sizes weighing from 1 to 150 carats. In color there is a variation almost white with a faint pink tone, through pink and lilac pink, into dark lilac. The gem is remarkably brilliant, no matter what the color. It is usually perfect and free from flaws, and, when pink, is one of the few natural stones of that color. The price has varied from $6 to $20 per carat, although generally it averages one-third the latter figure.—*Eng. and Min. Jour.*

CARNEGIE INSTITUTION WORK.

At the recent annual meeting in Washington, D. C., of the Board of Trustees of the Carnegie Institution, announcement was made that during the year 114 grants, aggregating $355,070, had been made to further researches in the several branches of science, and $1,000 paid to each of twenty-four research assistants for specified scientific investigation. The larger projects undertaken by the Institute during the year include: The establishment of a Department of Experimental Biology, with Stations at Cold Spring Harbor, L. I., and at the Dry Tortugas, Fla.; of a Department of Economics and Sociology; a Bureau of Historical Research; a Department of International Researches in Terrestrial Magnetism.

SPECIAL STEELS.

L. Guillet reports (*Comptes rendus*, 1904, CXXXIX, 540-542; *Bulletin* Société d'Encouragement, 1904, CVI) that in general the effect of molybdenum in steel is similar to that of tungsten, but the same result is effected with a smaller quantity of molybdenum, wherefore molybdenum steels may not be more expensive than tungsten steels, and frequently may be substituted for them with advantage. Titanium has practically no influence on the properties of carbon steels. Tin makes steel very hard and brittle. The tin dissolves in the iron and appears to form a compound with it. In tin steels containing not more than 10 per cent. Sn, all the carbon is in the form of pearlite. Tin steels thus resemble titanium steels more closely than they do silicon steels. R. A. Hadfield has patented (British, 25,794, November 26, 1903), an improved method of making manganese steel, which consists in adding an alloy containing 70 to 90 per cent. Mn and less than 3 per cent. C, preferably in a molten condition, to molten decarburized iron, in lieu of the ferro-manganese ordinarily used. In this way it is said to be possible to produce a low-carbon manganese steel which is much less liable to fracture than that heretofore produced.—*Eng. and Min. Jour.*

MAGNETIC STORMS AND SUN SPOTS.

Advices from London state that the data given by E. W. Maunder, superintendent of the solar department of Greenwich Observatory, who recently announced before the Royal Astronomical Society as to the familiar magnetic disturbances which derange the mariner's compass and their relation to sun spots, has created the deepest interest in astronomical circles.

In connection with magnetic storms some kind of solar activity has never been denied. The real point of Mr. Maunder's discovery is the fact that these storms recur at regular fixed intervals. After marking out the times that hundreds of storms were found, some of which corresponded to great sun spots and others which did not, he tried vainly to find a correspondence with the faculæ or flecks of boiling fire on the sun's surface and with the prominences.

At last he noticed that there were frequently a series of magnetic storms at intervals of exactly twenty-seven and one-third days. Sometimes there was no storm at the end of this period, but the storm was repeated after exactly two or three such intervals. Now, twenty-seven and one-third days is the exact time for a point on the sun to go once around and appear opposite the earth again. The storm arrives generally twenty-six hours after the sun spot points directly toward the earth. It is presumed that that time is taken in rushing up particles to reach the earth, though the storm comes again and again after the sun spot has vanished. It is generally just at the time when the place where the sun spot was, in passing; that is, the sun spot has gone, but a stream of magnetic commotion is still proceeding at the same point.

Still more remarkable is the discovery that there are certain favorite points on the sun for sun spots and magnetic streams which continue after the sun spots have vanished. One center of such disturbances is a point on the twenty-second degree of the sun's longitude. It has been pointed out that it is strange that this repetition of storms at intervals of twenty-seven and one-third days has not been noticed before, as Hornstein long ago announced that he detected a minute regular swing of the magnetic needles having the same period.—*Elec. World.*

CHEMICAL SECTION.

Stated Meeting, held Thursday, January 19, 1905.

A Simple Method of Calculating Water Analyses and Amounts of Substances to be Added for Preventing Scale and Corrosion in Boilers.

By Samuel S. Sadtler,
Member of the Institute.

The curves and tables described herewith are intended to fulfil two purposes :

(1) To save the time generally found necessary in calculating water analyses, both in finding the amounts of the bases and acids from the analytical data obtained and in apportioning these to find the probable constituents of the water.

(2) Having analysis of a water, to transpose it into other terms or to find the amount of certain correctives theoretically required.—The Editor.

It has been the experience of the writer that the time necessary to calculate a complete analysis of water for technical purposes (which has to include both sodium and potassium compounds in order to correctly judge the amounts and character of the alkaline earth combinations) is too large a percentage of the time devoted to the whole work. It is not only the time required to convert the quantities found in the analytical determinations into the oxides of the metals, but the still greater amount of time necessary to proportion them with the acid radicles.

In order to make a saving of time possible, I have prepared tables in which corresponding combining weights are referred to the molecular weight of chlorine (Cl_2) and values of from 1 to 9 are given in terms of chlorine, and observing the same ratio, values of chlorine (1 to 9) are then given in terms of all the other substances. The curves are based on the same relations and in addition to the factors represented in the tables, sodium carbonate and soda ash (52 per cent. Na_2O) are plotted, by which in addition to the CaO curve and the Na_2O curve, the calculations for correctives are much simplified. In the case where it is desirable to use lime the impurities must be allowed for, and in the case of sodium hydrate the value found from the curve must be divided by the percentage of Na_2O in the particular alkali used. The tables and curves are made applicable to several schemes of analysis as follows:

(*a*) That in which the bases are weighed in their usual combinations, with the alkalies as chlorides, and determined in a different sample from the heavy metals and earths.

(*b*) That in which all the determinations, with the exception of chlorine, are made in one sample and the magnesium, sodium and potassium are first weighed up as sulphates, a part of the magnesium afterwards being weighed as oxide and another portion as pyrophosphate. The several weighings containing the same base can be successively transferred into terms of chlorine or into the oxide of the base.

(*c*) A "primary factor" involving the ratio of magnesium chloride to chlorine is given, as the author has been informed that it may be possible to separate magnesium chloride from alkali chlorides by solution in an organic solvent.

Values of those substances never determined as such, are not given in whole numbers or "primary factors."

No relations of calcium sulphate are given in the table, for lack of space, as the values of CaO and So_3 found by the tables may be easily combined. Values for the alkali sulphates and magnesium sulphates are given because of their being sometimes weighed as such.

THE USE OF THE TABLES.

Authorities are somewhat at variance as to the proper way of uniting the basic and acid radicles so as to represent in the report the compounds as they exist in the natural water. This table, however, can be used with any system. The author combines the strongest acids with the strongest bases in turn, and what remains of either base or acid after one proportion is combined with the next strongest base or acid, as may be required. If the acid is in excess the base is converted into terms of chlorine by means of the table, as is also done with the acid. They are then subtracted. The smaller amount is then converted by means of the table into the compound sought, or in the case of lime and sulphuric anhydride into the oxides and added. The difference is put into the same terms as the next strongest basic radicle, or the opposite is done when the base is in excess. All values are given in terms of milligrams per liter or parts per million. Where more than 1 liter is used, the results are divided by that number, and where the results are to be stated in grains per gallon (U. S. or Imperial) the tables on the right-hand side of each page can be used for the conversion.

Where the amount found in milligrams consists of several figures, they are taken separately and the values found are added, the values corresponding to the second and third decimal places are added after dividing by 10 or 100.

To better exemplify the use of the tables the following analysis is calculated:

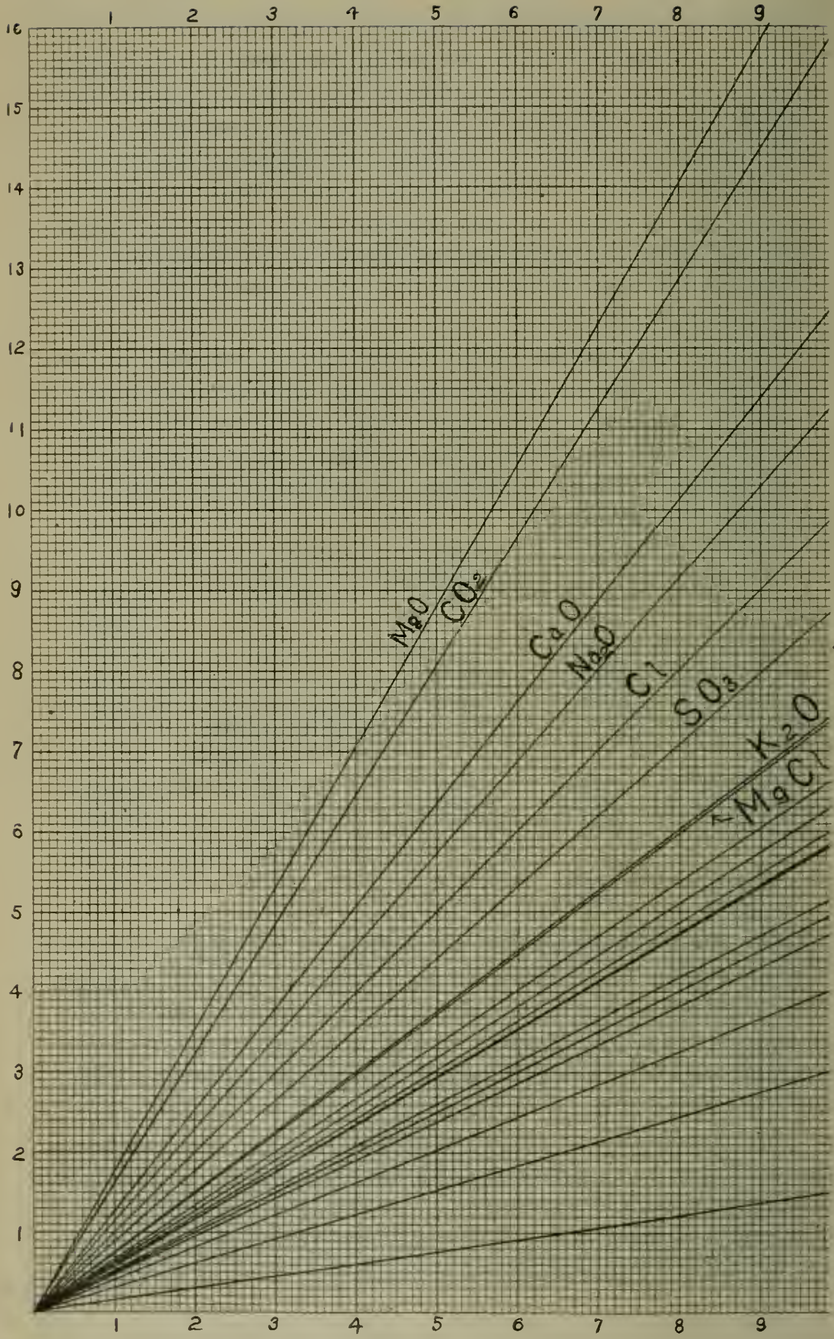
ANALYSIS.

	Grams per liter.	Cl Equiv.	Remainders.	Combined.
SiO_2	2·31			2·31 SiO_2
Fe_2O_3	4·16			4·16 F_2O_3
CaO	26·8	23·87		65·1 $CaSO_4$
$Mg_2P_2O_7$ . . .	24·18	14·18		26.3 $MgSO_4$.
$BaSO_4$	159·		Left from Mg 112.	
			" " Ca none.	
Alk. Chlorides	14·0	6·07	·20	10·2 NaCl
K_2PtCl_6 . . .	12·1	1·91	6·27	3·82 KCl
Cl	8·18			

12·1 gr. per liter, K_2PtCl_6 = 3·17 + ·614 + ·032 KCl = 3·82 KCl.

14·0 total alkaline chlorides — 3·82 = 10·2 NaCl as found by the table. The chlorine equivalents are also recorded and the remainder is ·20. This corresponds to ·314 MgP_2O_7, leaving 23·9. The $MgSO_4$ and chlorine equivalents are recorded, as the chlorine is used up and the chlorine equivalent of lime is found and sulphuric anhydride from this.

In the use of the tables with the method recommended in Stillman's Engineering Chemistry, and much used by analysts, where the solution is divided the quantities found should first be multiplied by 2, 3 or 4, as the case may be, to bring all figures to the same basis.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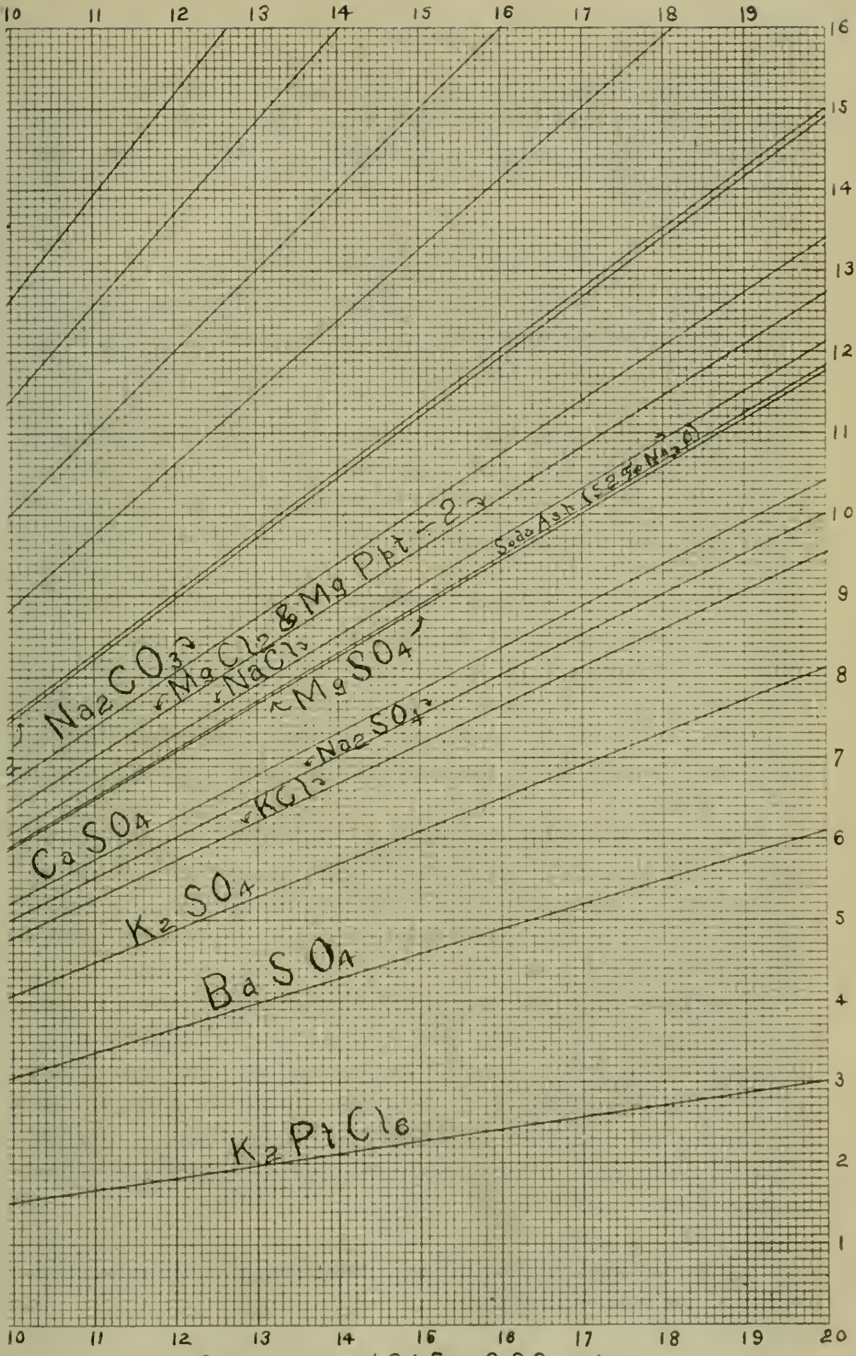

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In all cases the results are calculated in milligrams per 1 liter, no matter how many liters were taken and parts per 100,000 or grains per gallon recorded as the last step after using the tables.

THE USE OF THE CURVES.

In using the curves * the weights in milligrams per liter found are taken as abscissæ, and the points of intersection on the various curves are noted. The corresponding intersections on the curves of the substances which are to be reported are observed on the horizontal lines. From these intersections the values of abscissæ are again taken, which are the results required. Where there is an excess of elements or groups of opposite character the lines are drawn to the values of ordinates. For instance, 20 mg. of Cl equivalent are subtracted from the 30 mg. found by analysis, and the amount combined is taken on the line of ordinates. The corresponding intersection on the NaCl or KCl curve is then noted, and the amount of the compound recorded. The excess is counted from zero to the line of ordinates, where it is compared with the next strongest basic radical.

The alkalies when weighed as chlorides or sulphates need not be put in terms of the oxides as a step.

Both table and curves are only carried out to three places, as that is as great a degree of accuracy as is requisite in water analysis.

In applying the curves for boiler compounds, the amount of soda ash, caustic soda and lime are calculated for each separate corrosive or scale-forming substance and then added, or one corrective may be calculated for certain constituents and another for others. Attention is hereby called to the fact that less quantities of correctives than calculated are often found sufficient.

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* The author expects to have plates published giving all the calculations for calculating water analysis, etc.

Cl_2.	MgO.	CaO.	Mg ½ Ppt.	$MgSO_4$.	$MgCl_2$.	$BaSO_4$.	$CaCl_2$.	SO_3.	Parts per Mil.	Grains per U.S. Gal.	Grains per Imp. Gal.
1	·569	·790	1 57	1·70	1·34	3 29	1·57	1·13	36	2·0994	2.52
1·76	1	—	2·76	2·99	2·36	—	—	—	37	2·1577	2·59
1·26	—	1	—	—	—	—	1·98	—	38	2·216	2 66
·636	·362	—	1	1·08	·855	—	—	—	39	2·2745	2·73
·587	·335	—	·924	1	7·87	—	—	—	40	2·3327	2·80
·744	·423	—	—	1·27	1	—	—	—	41	2·391	2·87
·304	—	—	—	—	—	1	—	·342	42	2 4493	2·94
2	1·14	1·58	3·14	3·40	2·69	6·58	3·13	2·26	43	2·5076	3·01
3·52	2	—	5·52	5·97	4·72	—	—	—	44	2·5659	3·08
2·53	—	2	—	—	—	—	3·96	—	45	2·6243	4·15
1·27	·724	—	2	2·16	1·71	—	—	—	46	2·6826	3·22
1·17	·670	—	1·85	2	1 57	—	—	—	47	2·7409	3·29
1·49	·846	—	—	2·53	2	—	—	—	48	2·7992	3·36
·608	—	—	—	—	—	2	—	·684	49	2·8575	3·43
3	1·71	2·37	4·71	5·10	4·03	9·88	4·70	3·39	50	2·9159	3·50
5·28	3	—	8·28	8·96	7·08	—	—	—	51	2·9742	3·57
3·79	—	3	—	—	—	—	5·94	—	52	3·0325	3·64
1·91	1·09	—	3	3·25	2·57	—	—	—	53	3 0908	3·71
1·76	1·01	—	2·77	3	2.36	—	—	—	54	3·1491	3·78
2·23	1·27	—	—	3·80	3	—	—	—	55	3·2074	3·85
·912	—	—	—	—	—	3	—	1·03	56	3·2658	3·92
4	2·28	3·16	6·28	6·80	5·36	13·2	6·26	4·52	57	3·3241	3·99
7·04	4	—	11·00	11·9	9 44	—	—	—	58	3·3824	4·06
5·24	—	4	—	—	—	—	7 92	—	59	3·4407	4.13
2·54	1·45	—	4	4·32	3·42	—	—	—	60	3 499	4·20
2·35	1·34	—	3·69	4	3·14	—	—	—	61	3·5573	4·27
2·98	1·29	—	—	5·08	4	—	—	—	62	3·6157	4·34
1·21	—	—	—	—	—	4	—	1·37	63	3 674	4·41
5	2 85	3·95	7·85	8·50	6·70	16·5	7·85	5·15	64	3·7323	4·48
8·80	—	—	13·8	14·9	11·8	—	—	—	65	3·7906	4·55
6·32	—	5	—	—	—	—	9·90	—	66	3·8489	4·62
3 18	1·81	—	5	5·41	4·28	—	—	—	67	3·9073	4·69
3·94	1·67	—	4·62	5	3 94	—	—	—	68	3·9656	4·76
3·72	2·12	—	—	6·33	5	—	—	—	69	4·0239	4 83
1·82	—	—	—	—	—	5	—	1·71	70	4·0822	4·90

Cl_2.	CO_2.	NaCl.	K_2PtCl_6.	KCl.	Na_2SO_4.	K_2SO_4.	Na_2O.	K_2O.	Parts per Mil.	Grains per U.S. Gal.	Grains per Imp. Gal.
1	·620	1·65	6·86	2·10	2·00	2·46	·876	1·33	1	·0583	·070
1·61	1	—	—	—	—	—	—	—	2	·1166	·140
·606	—	1	—	—	1·22	—	·531	—	3	·1749	·210
·146	—	·241	1	·307	—	·359	—	·192	4	.2332	·280
·475	—	—	3·30	1	—	1·67	—	·632	5	·2915	·350
·500	—	823	—	—	1	—	·438	—	6	·3499	·420
·406	—	—	2 81	·856	—	1	—	·540	7	·4082	·490
2	1·24	3·30	13·7	4.20	4·00	4·92	·175	2·66	8	·4665	·560
3·22	2	—	—	—	—	—	—	—	9	·5248	·630
1·21	—	2	—	3	2·43	—	1·06	—	10	·5831	·700
·292	—	·482	2	·614	—	7·18	—	·384	11	·6414	·770
·950	—	—	6·00	2	—	3·34	—	1·26	12	·6998	·840
1·00	—	1·65	—	—	2	—	8·76	—	13	·7581	·910
·812	—	—	5·61	1·71	—	2	—	1·08	14	·8165	·980
3	1·86	4·95	21·0	6·30	6·00	7·38	2·63	3·99	15	·8747	1·05
4·83	3	—	—	—	—	—	—	—	16	·9330	1·12
1·82	—	3	—	—	3·65	—	1·59	—	17	·9914	1·19
·438	—	·723	3	·921	—	1·07	—	.576	18	1·050	1·26
1·43	—	—	9·90	3	—	5·07	—	1·90	19	1·108	1·33
1·50	—	2·47	—	—	3	—	1 31	—	20	1·1663	1·40
1·22	—	—	8·43	2·57	—	3	—	1 12	21	1·2246	1·47
4	2·48	6·60	27·4	8·40	8·00	9·84	3·50	5·34	22	1·2829	1·54
6·44	4	—	—	—	—	—	—	—	23	1·3413	1·61
2·42	—	4	—	—	4·86	—	2·12	—	24	1·3996	1·68
·584	—	·964	4	1·22	—	1·44	—	·768	25	1·4579	1·75
1·90	—	—	13·1	4	—	6·68	—	2·52	26	1·5162	1·82
2·00	—	3·29	—	—	4	—	1·73	—	27	1·5745	1·89
1·62	—	—	11·2	3·42	—	4	—	2.16	28	1·6329	1·96
5	3·10	8·25	3·43	10·5	10·0	12·3	4 38	6·65	29	1·6912	2 03
8·05	5	—	—	—	—	—	—	—	30	1·7495	2·10
3·03	—	5	—	—	6·07	—	2·66	—	31	1·8078	2·17
·730	—	1·21	5	1·53	—	1·80	—	·900	32	1·8·61	2·24
2·38	—	—	16.5	5	—	8·35	—	3·16	33	1·9244	2·31
2·50	—	4·12	—	—	5	—	2·19	—	34	1·9828	2·38
2·03	—	—	14·1	4.28	—	5	—	2 70	35	2·0411	2 45

Cl_2.	MgO.	CaO.	Mg ½ Ppt.	$MgSO_4$.	$MgCl_2$.	$BaSO_4$.	$CaCl_2$.	SO_3.	Parts per Mil.	Grains per U. S. Gal.	Grains per Imp. Gal.
6	3·41	4·74	9.42	10·2	8·04	19·7	9·42	6·78	99	5·7734	6·93
10·6	6	—	16·6	17·9	14·2	—	—	—	100	5·8318	7·00
7·56	—	6	—	—	—	—	11·9	—			
38·2	2·17	—	6	6·48	5·13	—	—	—			
3·52	2·01	—	5·54	6	4·72	—	—	—			
4·46	2·54	—	—	7·62	6·	—	—	—			
8·24	—	—	—	—	—	6·	—	2·05			
7	3 98	5·53	10·99	11·90	9·38	23·0	11·0	7·91			
12 3	7	—	19·3	20·9	16·5	—	2	—			
8·82	—	7	—	—	—	—	13·9	—			
4·45	2·53	—	7	7·56	5·99	—	—	—			
4·11	2·35	—	6·47	7	5·51	—	—	—			
5·21	2·96	—	—	8·89	7	—	—	—			
2·13	—	—	—	—	—	7	—	2·39			
8	4·55	6·32	12·6	13·6	10·7	26·3	12·6	9·04			
14·1	8	—	22·1	23·9	18·9	—	—	—			
10·1	—	8	—	—	—	—	15·8	—			
5·09	2·90	—	8	8·04	6·84	—	—	—			
4·70	2·68	—	7·39	8	6·30	—	—	—			
5·95	3·38	—	—	10·2	8	—	—	—			
2·43	—	—	—	—	—	8	—	2·74			
9	5·12	7·11	14·1	15·3	12·1	29·6	14·1	10·2			
15·8	9	—	24·8	26·9	21·2	—	—	—			
11·3	—	9	—	—	—	—	17·8	—			
5·72	3·26	—	9	9·72	7·70	—	—	—			
5·28	3·02	—	8·32	9	7·08	—	—	—			
6·70	3·81	—	—	11·4	9	—	—	—			
2·74	—	—	—	—	—	9	—	3 08			

Cl_2.	CO_2.	NaCl.	K_2PtCl_6	KCl.	Na_2SO_4.	K_2SO_4.	Na_2O.	K_2O.	Parts per Mil.	Grains per U. S. Gal.	Grains per Imp. Gal.
6	3·72	9·90	41·2	12·6	12·0	14·8	5·28	7·98	71	4·1405	4·97
9·66	6	—	—	—	—	—	—	—	72	4·1988	5·04
3·64	—	6	—	—	7·32	—	3·18	—	73	4·2572	5·11
·876	—	1·45	6	1·84	—	2·15	—	1·15	74	4·3155	5·18
2·86	—	—	19·8	6	—	10·02	—	3·79	75	4·3738	5·25
3·00	—	4·94	—	—	6	—	2·63	—	76	4·4321	5·32
2·44	—	—	16·9	5·14	—	6	—	3·24	77	4·4904	5·39
7	4·34	11·6	48·0	14·7	14 0	17·2	6·13	9·31	78	4·5488	5·46
11·3	7	—	—	—	—	—	—	—	79	4·6071	5·53
4·24	—	7	—	—	8·54	—	3·72	—	80	4·6654	5·60
10·22	—	1·69	7	2·15	—	2·51	—	1·34	81	4·7237	5·67
3·28	—	—	2·31	7	—	11·7	—	4·42	82	4·782	5·74
3·50	—	5·76	—	—	7	—	3·07	—	83	4·8403	5·81
2·84	—	—	19·7	5·99	—	7	—	3·78	84	4·8987	5·88
8	4·96	13·2	54·8	16 8	16·0	19·7	7·0	10·6	85	4·957	5·95
1·29	8	—	—	—	—	—	—	—	86	5·0153	6·02
4·84	—	8	—	—	9·92	—	4·24	—	87	5·0736	6·09
1·07	—	1 93	8	2·44	—	2·88	—	1·44	88	5·1319	6·16
3·80	—	—	26·2	8	—	13·4	—	5·04	86	5·1903	6·23
4·00	—	6·58	—	—	8	—	3·46	—	90	5·2486	6 30
3·24	—	—	22·4	6·84	—	8	—	4·32	91	5·3069	6·37
9	5·58	14·9	63·0	18·9	18·0	22·1	7·89	12 0	92	5·3652	6·44
14·5	9	—	—	—	—	—	—	—	93	5·4235	6·51
5·46	—	9	—	—	11·0	—	4 77	—	94	5·4818	6·58
1·31	—	2·17	9	3·66	—	3 21	—	1·73	95	5·5402	6·65
4·29	—	—	29·7	9	—	15·2	—	5·70	96	5·5985	6·72
4·50	—	7·41	—	—	9	—	3 93	—	97	5·6568	6·70
3 66	—	—	25·3	7 71	—	9	—	4·86	98	5·7151	6·86

THE FRANKLIN INSTITUTE.

Radium and Radio-Activity in General.*

By Robert H. Bradbury.

The atomic theory. The atom an unalterable existence. The radium rays. Corpuscles α-, β- and γ-rays and their effects. The radium emanation. Excited or secondary radio-activity. The radio-active process in comparison to ordinary chemical changes. Its uncontrollable character. Enormous amount of energy evolved. Radio-activity in general. Thorium. Radio-activity of ordinary substances. The evolution of matter.—The Editor.

I. THE ATOMIC THEORY.

The idea that matter is composed of particles with vacant spaces between them is very ancient. It was clearly stated by Democritus, Lucretius and others. But it is only since its restatement by John Dalton, just a century ago, that it has become a scientific doctrine.

The number of different substances known is enormous. Over 100,000 compounds of carbon alone have been prepared; yet when these materials are decomposed or separated into their constituents, we discover that the chemistry of the universe is not so inextricably complex as might be supposed, for as a final result of this decomposing or analyzing process, only about ninety *elements* have been obtained. These are the ultimate constituents of the material world. It is impossible to decompose them into simpler bodies, and it is equally impossible to transform one element into another.

According to the atomic theory, this means that there are only about ninety kinds of atoms. These atoms can combine with one another in an infinite variety of ways,—hence the multitudinous compounds which exist in nature, or have been prepared artificially. Thus, hydrogen (an invisible gas) burns in oxygen (another invisible gas) and water is produced. In this process two atoms of hydrogen unite with one atom of oxygen and produce a compound particle of water which is a group composed of the three. The water can easily be separated into the two gases again, and when this is done the group of three atoms is broken up and the hydrogen and oxygen atoms are again separated.

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*A popular lecture delivered before the Franklin Institute, in Association Hall, Philadelphia, Friday November 18, 1904.

Now, in this union and subsequent separation the atoms of hydrogen and of oxygen are not altered, broken up or destroyed. They are differently grouped, that is all. When an element—as in this case—disappears to form a compound it can always be recovered unchanged in quantity when the compound is decomposed. Accordingly, its atoms have not been modified in any way, but have simply entered into a union with those of the other elements. And from this union they secede—absolutely unchanged—when the compound is split up. It is clear, also, that the fact that one element cannot be converted into another indicates that the atoms are incapable of mutual transformation; that an oxygen atom, for example, cannot be separated into hydrogen atoms.

Thus there grew up, upon a most extensive and solid basis of fact, the conception of the atom as an unchanging existence. Its relations to the other atoms could be changed, but no alteration of any sort could be brought about in the atom itself. Not only the total quantity of matter in the universe, but also the quantity of each chemical element was regarded as constant. Physics takes us to the molecule and leaves us there. Chemistry takes us inside the molecule and informs us about the number and grouping of the atoms. Into the *atom* it was impossible for science to penetrate.

II. THE RADIUM RAYS.

Now, within the last decade we *have* penetrated into the atom and learned something about its structure. Still more surprising, we have observed and studied the transformation of one element into another. Substances like radium have been discovered which are continually emitting in straight lines something which, for want of a better name, we may call *rays*. These rays affect the photographic plate, and this property led to their detection. Afterward it was found that they have many other remarkable properties, which will be briefly discussed almost immediately. Just now we are specially concerned with the fact that it has been shown beyond doubt that the rays are *material*. Radium continually emits a bombardment or continuous rain of particles with prodigious speed—a speed approaching that of light. By various methods the particles which are continually shot off have been weighed, and they are found to be very much lighter than any atom. The smallest are only about $\frac{1}{1000}$ as heavy as the hydrogen atom, which is the lightest atom known. The radium atom, then, is continually going to pieces, constantly shooting off minute corpuscles with a speed which would take them around the world in about one-fifth of a second. It is inconceivable that such a speed should be given suddenly to the corpuscle. *It must already possess it inside the atom.*

Thus we are led to think of the atom of radium, and probably of other elements, as a system of small particles, all in very rapid motion. Now and then it happens that a particle acquires such a velocity that the forces—probably electrical in nature—which hold it in the atom are no longer sufficient, and it flies off into space with the speed which it possessed at the moment the atom was forsaken.

This opens up two questions: (1) What are the nature and effects of the particles shot off? (2) What becomes of the portion of the radium atom which remains behind? These questions we shall endeavor to answer in turn.

III. THE RAYS IN DETAIL.

(*a*) *The α-rays.*—Investigation has shown that there are at least two kinds of corpuscles projected from a sample of radium. There is, in the first place, a comparatively large particle, which is thrown of with a speed only $\frac{1}{10}$ that of light, say, 20,000 miles a second. This particle is about four times as heavy as the hydrogen atom and we have every reason to believe that it is an atom of *helium*. These streams of relatively large and slow-moving particles are called the α-rays. I have here an instrument devised by Sir Wm. Crookes, by which the blow which the α-particle delivers as it strikes an object is actually rendered visible. It is called the *spinthariscope*. It consists of a brass tube about 2 inches long. In one end is a screen coated with a compound of sulphur and zinc. Close to this is fixed a little copper arrow carrying a trace of radium. In the other end of the brass tube is a lens for better observation. If, after resting the eyes in perfect darkness, you look into the lens, what you see resembles a starry sky, but with the difference that the stars are constantly in motion. Each α-particle, as it strikes the screen, produces a flash which asts only for an instant, then the eye is attracted to some, new place, and so on. The sight is an impressive one, and rightly so, for each flash registers the death of an atom and this is as sublime a spectacle in its way as the death of a universe, though at the other end of the scale of magnitudes.

Since the α-particle is large and not very speedy it is easily arrested. If a radium preparation is wrapped in a sheet of writing paper or a thin layer of aluminium foil, the α-rays are stopped completely, and the β- and γ-rays alone pass through and can be studied separately. Even a few centimeters of air have the same effect. It must be remembered, however, that the term "slow" is only applied to the α-particles by comparison with the more swiftly-moving β-particles. Compared with that of any projectile, the speed of the α-particle is enormous. Weight for weight, for instance, it has 600,000,000 times the energy of motion of a rifle bullet.

(*b*) *β-rays.*—The β-rays have been shown to consist of material particles of about $\frac{1}{1000}$ the mass of the hydrogen atom. Their speed approaches but does not quite equal that of light. On account of their small size and great speed they penetrate matter about 100 times as readily as the α-rays. We may consider that ordinary matter bears much the same relation to them as a very coarse net to an extremely small and agile fish. The β-rays are identical with the *cathode* rays, which are formed at the negative pole when electric discharges pass through a vacuum tube. They are chiefly responsible for the effect of radium preparations upon the photographic plate.

Both the α- and β-rays are turned out of their course by an electric or magnetic field. This is a proof that they are composed of material particles. In the case of the α-rays the deflection is slight, and its direction shows that each particle carries a *positive charge*. The β-particles are deflected to a much greater extent and in the opposite direction, showing that each particle is charged *negatively*. Calculation shows that, taking the α- and β-rays together, three trillion's of particles escape from an ounce of radium per second.

(*c*) *The γ-rays.*—The γ-rays are the most penetrating. They can readily be detected after passing through the human body or a foot of solid iron. A plate of aluminium, 3¼ inches thick, cuts them down to one-half their value. There is still some question as to the nature of the γ-rays. They are not at all deflected by an electric or magnetic field, so there is no proof that they are material. They may consist of streams of uncharged particles shot off with immense speed. Uncharged particles would not be deflected, but it is more likely that they consist of an ethereal vibration identical with the Röntgen rays. It seems reasonable to suppose that when a particle is pitched off, the atomic convulsion would set up a shiver in the contiguous ether.

(*d*) *Effects of the Rays.*—Under this head we shall discuss the effects of the three kinds of rays together, just as they escape from the preparation of radium. It must be remembered, however, that if the radium is sealed up in a glass tube, which is commonly the case, the α-rays produce very little result, since they are almost entirely stopped by the glass.

Many substances exposed to the rays become luminous. Zinc sulphide and the diamond are examples. The latter lights up brilliantly, and this has been proposed as a method of distinguishing the gem from its imitations, which remain unaffected. Strong radium preparations are themselves luminous, and may give a light strong enough to read by. But, aside from the rarity of the substance, the presence of large quantities of high-grade radium preparations in the household would be attended with such serious danger that it will never be used as a source of light.

Radium compounds also continuously give off heat. A piece of pure radium would in an hour produce enough heat to raise its own weight of water from the freezing to the boiling point. This means that it would boil 8,760 times its weight of freezing water per year.

The glass in which a radium preparation is kept becomes light violet and finally black. Salt and similar substances are colored blue or green. Dry air, which is ordinarily an insulator, acquires the ability to conduct the electric current under the influence of radium rays, and other gases behave similarly. This effect has been used extensively in measuring the strength of radium preparations, and in investigating the nature of the rays, since it is much more convenient and exact than the photographic action.

The property of the rays of causing the air to conduct the current is so important in the study of the subject that we will endeavor to show it to you on the screen. The *lantern electroscope* which we shall use for that purpose is the property of Dr. John H. Shober, and I am indebted to his kindness for the use of it to-night. It consists essentially of a metal rod, at the upper part of which is attached a strip of aluminium foil. The whole is insulated and supported in a glass box in such a way that the image can be thrown upon the screen by the lantern. You notice that the strip of foil hangs down in contact with the rod, but when the apparatus is charged you observe that the foil stands out at right angles to the rod, because similar electric charges repel each other. This position it will retain for a long time, for since the air is practically an insulator, the charge is lost very slowly. Now a sealed tube containing some radium of 7,000 strength (rather a weak preparation) is introduced.* Immediately the air in the apparatus becomes a conductor and the charge leaks away. You observe that the aluminium leaf gradually falls till it is in contact with the rod. A repetition of the experiment yields the same result. Other things being equal, of course a stronger radium preparation would make the aluminium leaf fall more quickly. With a preparation of 300,000 strength* the fall of the aluminium leaf is instantaneous. It is clear that the method can be used quantitatively. Radium can be identified and determined by it in substances in which the quantity is so small that it would be entirely hopeless to search for it, even by spectroscopic methods. It has been calculated to be about 1,000,000 times as delicate as the spectroscope, and, as you see, it is very rapid and does not entail the loss or destruction of any of the sample tested. Of course, to attain such accuracy requires special elaborate apparatus.

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*It is customary to state the strength of radium preparations in terms of the radio-activity of uranium taken as a unity.

Paper turns brown and falls to pieces under the influence of radium rays. The action on living things is mainly destructive. Seeds lose the power of germination. Some investigators report that bacteria are destroyed, but there is some doubt about this, and it is probable that different organisms differ in their susceptibility. Leavened dough fails to rise if a strong radium tube is buried in it, but when the tube is removed fermentation goes on, so that the yeast is temporarity paralyzed, not killed. *Enzymes* are destroyed. Perhaps the most remarkable of all the effects of the radium rays is their power to prolong indefinitely the larval stage of certain insects. The strength and distance of the radium tube must be carefully chosen; otherwise the worms are killed. When these conditions are right the worms remain in the larval state, while others in a bottle not containing a radium tube have passed through twenty-four generations. The tadpole stage of the common frog is prolonged in somewhat the same way by a radium tube of proper strength suspended in the water, but in this case eccentricities of growth occur and monsters are produced. When a strong radium tube is suspended over white mice they appear to be unaffected for several days, then the hair falls out and death results after a week or more. Rabbits act similarly. There are indications that weaker radium preparations have a stimulating effect upon the growth of the hair and the vital functions generally of these animals.

The effect of the rays from a strong preparation upon the human body is similar to a severe burn, the chief difference being that nothing is noticed until some days after the exposure. To alter slightly a remark of Curie's, a pound of radium would probably destroy the human population of the planet, if each person were subjected to its influence for a time. For several days nothing would be noticed. Then the hair would fall out, the sight would be lost, the skin all over the body would become one continuous burn, and death would result.

IV. THE EMANATION.

What becomes of the radium atom when the particle which has produced the ray has been pitched off? What is the nature of the substance formed of the residual atomic fragments? It can no longer be radium, for a vast amount of chemical experience shows that a difference in atomic or molecular weight is always correlated with a difference in properties, and that the variation in the latter may be profound when the change in the former is relatively small. Compare, for instance, the properties of gold (atomic weight, 197·3) with those of mercury (atomic weight, 200), or those of lead (atomic weight, 207) with those of bismuth (atomic weight, 208).

Investigation shows that the residual substance is a *gas* which is continually escaping from radium compounds. It can be passed through glass tubes and preserved over mercury. When it is passed through a tube sunk in liquid air it is liquefied, producing a bright phosphorescence in the tube. It is *dense*, as shown by its rate of diffusion. It is somewhat soluble in water. It resembles helium and its allies in refusing absolutely to take part in any chemical reaction —all attempts to induce it to unite with other substances have failed. It is *poisonous*, for animals made to breathe air which has passed over a strong radium preparation die, although they are screened from the rays, and the air is entirely freed from any dust or powdered radium which might conceivably be carried with it. The lesions—as might be expected—are different from those produced by the rays. Instead of superficial burns we find congested and inflamed lung-tissue.

This gas is strongly radio-active, much more so than radium itself. Its atoms explode, shooting off particles just as the radium atoms do, but the atoms of the emanation are much more unstable, that is, a larger fraction of them explodes in a given time. Thus while it would require 1500 years for one-half of the atoms in a given mass of radium to disintegrate in this way, one-half of the atoms in a mass of the emanation would require only four days to do the same thing. Therefore, it will never be possible to prepare and handle the emanation in quantity, for the bombardment and the resulting development of heat would at once melt and destroy any vessel in which it might be placed.

V. EXCITED RADIO-ACTIVITY.

What becomes of the *emanation* when each atom of it has pitched off a particle, producing a ray? Something must be left, and for the reason stated above this something cannot be either radium or emanation. This time the substance is *solid.* It deposits on the surface of bodies and makes them temporarily radio-active. Thus every object exposed to the *emanation*—not the rays—acquires radio-activity, and retains it until the atoms of the invisible film of solid matter deposited on it have all exploded. Material makes no difference. Mica, copper, aluminium, cardboard, glass, ebonite—all become equally radio-active under the same circumstances. But it is a remarkable fact that if a metallic object—say a wire—which is exposed to the emanation is charged negatively, it acquires all the radio-activity, surrounding surfaces getting none of it.

This excited radio-activity is due to a film of solid matter on the surface, for it can be dissolved away by certain liquids, or wiped off with a piece of cloth or leather. Then the radio-activity is transferred to the liquid, the cloth or the leather, as the case may be. But the amount of solid matter present must be incredibly small, for it is totally invisible, and absolutely no gain in weight can be detected when a wire is made strongly radio-active. Thus this solid, of which an immeasurably small quantity can produce such great effects, must be thousands of times as active as radium itself. This means simply that its atoms are less stable, and a much larger proportion of them explodes in a given time. Therefore, the radio-activity must be transient. In fact, in half an hour half of the atoms of the film have undergone the change, and the excited radio-activity has fallen to one-half its original value.

VI. THE RADIO-ACTIVE PROCESS.

Thus the atoms of radium are unstable. They expel a positively charged particle, producing an α-ray, which shoots off, and the substance left behind is the emanation. The atoms of the emanation are still more unstable. Each of them expels an α particle, producing the solid, which is responsible for excited radio-activity. That the atoms of this solid also disintegrate we know—otherwise it would not be radio-active. But the changes which occur in the solid are complicated and difficult to study since the products are also solid and remain mixed with the substance from which they are derived. Rutherford* states that probably at least four successive changes takes place in the solid. It is important to note that the change of radium to the emanation, of the emanation to the solid and the first changes in the solid only expel α-rays. It is only in the last transformation through which the solid passes that the β and γ rays are also produced. Here is Rutherford's tabular view of the series of transformations through which radium passes:

Substance.	Nature of Rays Produced.	Nature of Substance.
Radium.	α	Metal analogous to calcium.
Emanation.	α	Dense gas, inert, chemically condensed at —150° C.

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* "Radio-activity," p. 326. This is an admirable book for one who wishes to take up the subject seriously.

Substances.	Nature of Rays Produced.	Nature of Substance.
First Solid.	α	Attaches itself to surfaces of bodies, from which it is driven off as vapor by a white heat. Soluble in some acids, but not in others.[*]
Second Solid.	No rays.	
Third Solid.	α, β and γ.	
Fourth Solid.	α and β	
Final product.		

It will be seen that there are six changes through which the restless radium atom passes before it finally finds peace in the production of a substance which is not radio-active, and, therefore, permanent. This final product is *helium. Both radium and helium are undoubtedly elements, and we have here the first case of the transformation of one element into another.*

This revolutionary fact—the transformation of radium into helium—was suspected by Rutherford, proved experimentally by Ramsay, and confirmed by sceptical German observers who expected to disprove it. Helium is a colorless, odorless gas, which is easily identified, and which, like the emanation, is inert chemically, refusing absolutely to take part in chemical changes. This change of one element into another is so entirely novel that it is desirable to examine the process, and to compare it with the ordinary chemical reactions, multitudes of which have been most carefully studied. In making this comparison we must remember that this is the first time the chemist has been permitted to *penetrate into the atom.* He has altered the grouping of atoms almost at will, and has produced upwards of a hundred thousand new groupings of the carbon atoms alone with those of other elements, but he has never before been able to study the disintegration of the atoms themselves, nor to effect any alteration in them.

Since, therefore, the radio-active process is so profoundly different from ordinary chemical transformations we should expect it to exhibit corresponding differences of behavior, and, as a matter of fact, it does, for there are at least two aspects of it which are so absolutely novel that they appear at first, to the trained chemical mind, bizarre and incredible.

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[*] This refers to the mixture which is obtained in experiment. The properties of the solids separately have not been determined.

Ordinary chemical changes are extremely sensitive to external circumstances; therefore by altering these circumstances they are easily controlled. Thus they proceed much more rapidly at high than at low temperatures. A rise of 10° C. on the average about doubles the speed. Many chemical processes are affected by light. Photography is based upon a mass of chemical changes which occur under the influence of light, and not in the dark. There are many reactions which are brought about by the aid of pressure, the electric current, Röntgen rays and so on.

Now the change through which radium passes and which ends in the production of helium is totally unaffected by external circumstances. It takes place at the same rate in absolute darkness as in the brightest light. Röntgen rays have no effect upon it. Its speed is exactly the same in liquid air at a temperature of about —190° C. as at a red heat. Even the rays from a radium preparation have no effect on the rate of change of another radium preparation. Similar statements might be made for all the factors which chemists are accustomed to employ to regulate the speed of chemical changes. The result is that the radio-active process is not under human control. It proceeds, paying no attention to externals, and we are powerless to bring it about or to stop it, to accelerate it or to retard it.

The other remarkable feature of radio-active change is the enormous amount of energy evolved during the transformation. The most energetic chemical process known (weight for weight) is the union of hydrogen with oxygen to form water. When 1 gram of water is produced, enough heat is formed to raise the temperature of 4,000 grams of water 1° C. No chemical change is known which liberates so much energy for the same weight transformed. Now the total heat liberated when 1 gram of radium transforms itself into helium through the successive steps which we have briefly traced is about *1,000,000 times as great as this.** It will be seen that the quantity of energy evolved in the radio-active change is of a different order from that liberated in ordinary chemical processes. In fact, a pound of radium would contain as much energy as several hundred tons of nitroglycerine, and if the energy could all be liberated at once it would produce an explosion of unimaginable violence. Aside from the difficulty of obtaining so much radium, we must remember, however, that it will probably never be possible to quicken the rate at which its energy is emitted.

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* Rutherford, p. 336.

VII. RADIO-ACTIVITY IN GENERAL.

Thus the atom of radium contains an enormous supply of energy which is gradually liberated, and this liberation is coincident with a number of successive transformations of the substance which end in the production of helium. Several other elements are known which exhibit similar phenomena, but in a much less intense degree. The radioactivity of *thorium* has been carefully studied by Rutherford. In general character it is quite similar to that of radium. There is a *thorium emanation* which is intensely radio-active, which is transformed into a solid. This solid attaches itself to the surfaces of bodies and makes them temporarily radio-active, and so on. The chief difference is that in the case of thorium the changes take place about 1,000,000 times more slowly. This means that, if we imagine a quantity of radium and a quantity of thorium weighed off so as to contain the same number of atoms, about 1,000,000 times as many atoms would explode per second in the radium as in the thorium. It has been shown that, given a quantity of pure radium to start with, $\frac{1}{2000}$ of it would disintegrate per year. In 10,000 years practically all of it would have run its course. The rate of change of thorium is approximately given by mutiplying both of these periods by 1,000,000. But the total energy given off is probably of the same order in the two cases. It is only the speed which is different.

Are the atoms of all matter similarly constituted? Is radio-active change constantly taking place in ordinary matter? Are radium, thorium and the rest of the radio-active elements simply those in which the number of atoms which disintegrate per second is so large that the process is easily detected? These are far-reaching questions. The obvious way of getting an answer to them is to test ordinary matter, like silver, platinum, copper, and so on, for radio-activity. Strutt has done this with great care, and his result is that all ordinary substances appear to possess a slight radio-activity. Unless this is due to a faint trace of a radio-element, it opens a vista of thought which staggers the imagination. A slow—inconceivably slow—process of evolution is taking place in the matter around us. Billions of times more slowly than radium, the elements are changing into something else. Matter has had a beginning and will have an end. So much we can see, but the beginning and end may remain forever unknown to us.

CENTRAL MANUAL TRAINING SCHOOL,
DEPARTMENT OF CHEMISTRY.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, February 15, 1905.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 15, 1905.

VICE-PRESIDENT WASHINGTON JONES in the chair.

Present, 42 members and visitors. Additions to membership during the previous month, 14.

The paper of the evening was read by Mr. John W. Hill, Chief Engineer of the Bureau of Filtration, Department of Public Works, Philadelphia, "On the Construction, Examination and Repair of the Torresdale Conduit."

The speaker illustrated his remarks very fully with the aid of lantern photographs.

The paper was discussed by Mr. Spencer Fullerton, Mr. E. M. Nichols, Dr. E. Goldsmith and the author.

On Dr. Goldsmith's motion the meeting passed a vote of thanks to Mr. Hill for his interesting communication.

Mr. John E. Alexander followed with a description of an improved phonograph of his invention, known as the "phonosphere," and gave a demonstration with the apparatus.

Adjourned.

WM. H. WAHL,
Secretary.

Committee on Science and the Arts.

(*Abstract of proceedings of the stated meeting held Wednesday, February 1, 1905.*)

DR. E. GOLDSMITH in the chair.

The annual election resulted in the choice of Dr. E. Goldsmith as Chairman for the current year.

The following reports were adopted:

(No. 2329.) *Knitting Machine.*—Edward Parkinson, Philadelphia.

ABSTRACT: This invention is protected by letters patent of the United States, No. 739,708, September 22, 1902, granted to applicant, and relates to that class of knitting machines known as single-plate straight knitting machines. The object of the improvements is: (1) to largely increase the capacity of machines of this class, and (2) to furnish a knitting machine with means whereby two threads will be successively engaged by the needles to form a fabric in different colors in either a plain stitch, in a tuck stitch, in a cross-stitch, or in any desired combination of these stitches; (3) to furnish means for the convenient and rapid substitution of different colored threads for any particular thread being operated upon, and (4) to furnish positive means for lifting and closing the latches of the needles.

The Committee's report concedes the correctness of these claims, and in recognition of the advance in the art which the invention represents, recommends the award to the applicant of the John Scott Legacy Premium Medal. (*Sub-Committee:* Henry R. Heyl, Chairman; Hugo Bilgram.)

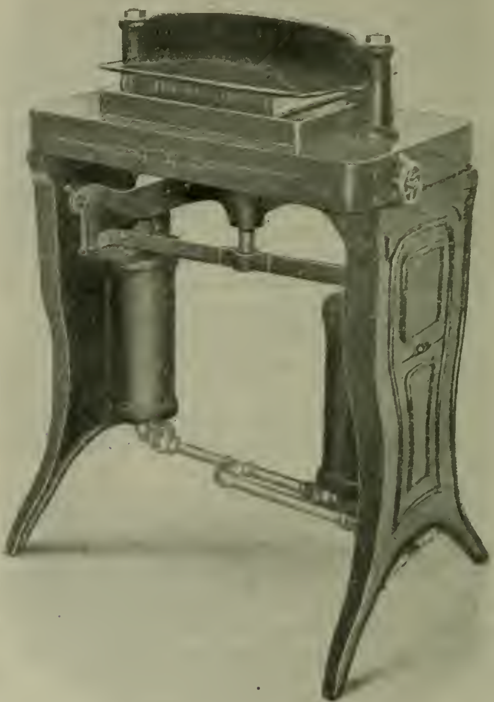
(No. 2342.) *Automatic Hydraulic Letter-Copying Press.*—Walter A. Rosenbaum, New York.

ABSTRACT: This invention is covered by letters-patent of the United States, No. 756,530, April 5, 1904.

The report confirms applicant's statements that the invention is unique in its class, being entirely automatic in action, and actuated by the public water supply. The pressure applied is uniformly distributed over the surface of the press, and the amount of pressure may be multipled at will.

The water-power is led to two hydraulic cylinders, secured by means of brackets to the table or standard of the letter press. These brackets are hollow, to receive the pistons, and fulcrumed to each cylinder is a lever which, at its outer end, enters a slot in the bracket of the opposite cylinder, and bears on the top of the piston. The arrangement is such that the two levers lie parallel, and an equalizing lever is placed diagonally across them. The equalizing lever transmits pressure to a platen through a ball-and-socket joint, the socket being formed with a circular rubber cushion to take up any inequalities in the thickness of the book, and render the pressure uniform over the entire book surface. The copying book is pressed upward by the platen against a pressure plate, which is mounted on extensions of the cylinder bracket. The flow of water in the cylinders is controlled by a three-way valve, which is operated by a small hand-wheel conveniently placed near the top of the table.

The report concludes that the press is a useful and practical device, well designed and constructed for its intended purpose, and that it will meet a long-felt need in offices where much copying is required and high pressure is needed. The award of the John Scott Legacy Premium and Medal is recommended. (*Sub-Committee:* Geo. S. Cullen, Chairman; James S. Rogers.)



(No. 2348.) *Safety-Elevator Devices.*—Standard Elevator Interlock Company, Philadelphia.

(Report protested by applicant.)

(No. 2345.) *Products* of the Flexible Compound Company, Philadelphia. (Progress.)

(No. 2354.) *Railway-Car Cuspidor.*—Emanuel Metzger, Kingston, N. Y. (An advisory report.) W.

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THE FRANKLIN INSTITUTE

Stated Meeting, Held Wednesday, February 15, 1905.

The Torresdale Conduit.*

BY JOHN W. HILL,

Chief Engineer, Bureau of Filtration, Philadelphia.

The Torresdale Conduit, constituting, as it does, one of the important elements of the great filtration system for the improvement of the water supply of Philadelphia, would, on account of its magnitude alone, command the interest of engineers. It has, however, been made the subject some criticism. In this paper, the author, who was Chief Engineer in charge of its construction, presents, with ample illustrations, a complete history of the work of construction, the subsequent examination, and present condition of the work.—THE EDITOR.

The Torresdale Conduit, Contract No. 14, Improvement, Extension and Filtration of the Water Supply of Philadelphia, is a large inverted syphon intended to conduct the filtered water from the clear water basin at Torresdale to the pumping station at Lardner's Point. Its nominal capacity is 300,000,000 gallons per day of twenty-four hours, with a loss of head between end shafts of 8.6 feet, and a mean velocity of flow of 5.276 feet per second.

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*A paper read before the Engineers' Club of Philadelphia, and repeated by request before the Institute.

Influent Shaft No. 1, is located 1,525.5 feet south of the center line of Pennypack street, at the Torresdale Filters, and from this point the conduit proceeds upon city property, under Pennypack Creek, and through the House of Correction grounds to Holmesburg Avenue; thence south on Eugene Street, as laid down on the City plan, to its intersection with Delaware Avenue; thence south on Delaware Avenue to Effluent Shaft No. 11, at Lardner's Point Pumping Station. The nine intermediate working shafts were distributed along the line of work at locations about 1,400 feet apart, making thus the average length of heading about 700 feet.

The depth of Shaft No. 1, at the Torresdale end of the Conduit, measured from the finished head, is 127.39 feet, and of Shaft No. 11, at Lardner's Point, from same point of measurement, 117.05 feet. The length of tunnel between end shafts is 13,809.2 feet, and total length of water flow from the center of influent legs at Shaft No. 1 to the center of effluent legs at Shaft No. 11, about 13,968.5 feet. The diameter of Shaft No. 1 of the tunnel and the lower 68.1 feet of Shaft No. 11 is uniformly ten feet seven inches on the neat lines of brickwork. The upper 48.9 feet of Shaft No. 11 is twenty-one feet one inch diameter.

The general depth of the center line of tunnel is about 100 feet below ground level.

The filtered water is drawn from the clear water basin at Torresdale to Shaft No. 1 through a concrete metal reinforced conduit of horseshoe section, equivalent in area to a circle 10 feet in diameter, 855 feet long from the outlet of the clear water basin to the shaft. This conduit is connected with the shaft at elevation 186.50 T. D. center line, through two cast-iron nozzles bolted to the steel shell of the shaft, one eight feet diameter, and the other seven feet diameter, the direct connection to the conduit being made through the larger nozzle. Each of the nozzles is connected with the conduit and the clear water basin through lengths of riveted steel pipe, twenty-one feet long for the eight foot nozzle, and fourteen feet long for the seven foot nozzle, the steel pipes being enveloped in concrete.

The effluent legs at Shaft No. 11 are respectively fourteen

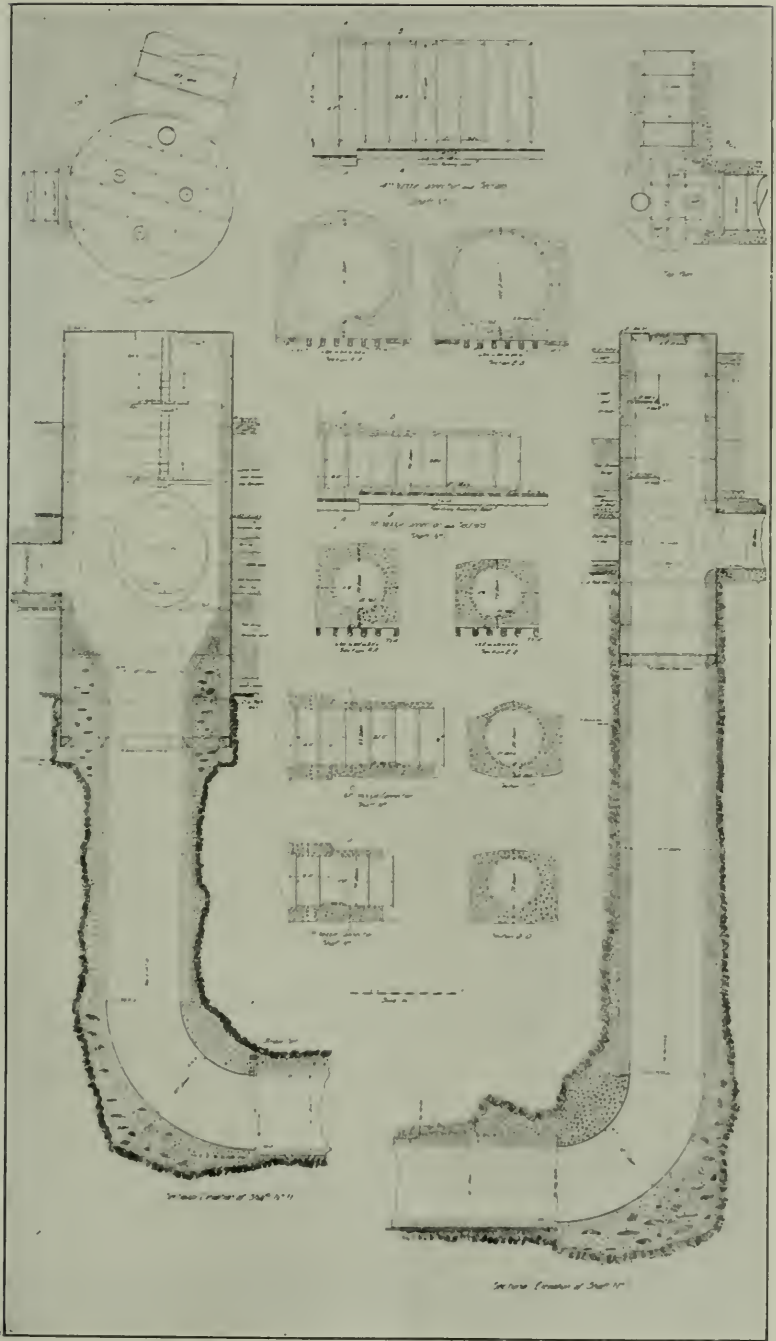

PLATE I.—Typical Sections of Shafts No. 1 and No. 11.

feet and seven feet diameter, of riveted steel, each twenty-eight feet in length, and, like the influent legs at Shaft No. I, are connected to the steel shell of the shaft with cast-iron nozzles, and rounded mouthpieces.

The elevations of the conduit and connections with reference to Torresdale Datum are as follows:

Head of Shafts Nos. I and II	216.46
Invert of tunnel at Shaft No. I	89.07
Invert of tunnel at Shaft No. II	99.41
Center line of tunnel at midlength	99.49
Invert of 8-ft. connection at Shaft No. I	182.50
Invert of 7-ft. connection at Shaft No. I	182.50
Invert of 14-ft. connection at Shaft No. II	178.00
Invert of 7-ft. connection at Shaft No. II	178.00
Floor clear water basin, Torresdale	192.00
High water line, clear water basin, Torresdale	207.00
Invert of 10-ft. Conduit from C. W. Basin to Shaft No. I	181.50

[Torresdale Datum is 200 feet below City Datum, or 200 feet below mean high water in the Delaware River, Philadelphia.]

Down to the rock, and for a short distance into it, until the shells were sealed, the permanent and working shafts were made of steel plate lined with brick. Below the rock the permanent shafts are lined with brick backed with concrete. The working shafts were not thus lined, but the rock left in the condition found after blasting.

The bends at the bottom of the shaft are entirely of concrete, built to forms ten feet seven inches diameter, on a radius of center line of fifteen feet nine inches diameter, finished with a granolithic surface one inch thick. The tunnel is lined with hard-burned brick backed with concrete.

The lining of invert is everywhere of two courses of brick, laid to templets on a cradle of concrete. The arch ring varies from three to five courses of brick, depending upon the nature of the material in the roof of the tunnel, above which concrete was packed up to the rock, and where, for lack of space above the arch ring, concrete could not be placed, the voids were filled with Portland cement grout pumped in under about eighty-five pounds pressure per square inch. The grout was usually pumped through the weeper pipes set in the brick masonry to lead the water from back of the arch to the interior of the tunnel or shaft.

Considering the carrying capacity of 300,000,000 gallons per day, the velocity at different points between the clear water basin at Torresdale and the pump wells at Lardner's Point will be as follows:

	Ft. Per Second
From the clear water basin at Torresdale to Shaft No. 1	5.92
Combined 8-ft. diameter and 7-ft. diameter nozzles at Shaft No. 1	5.163
Shaft No. 1 and tunnel	5.276
Shaft No. 11 at lower end	5.276
Shaft No. 11 at upper end	1.319
Aqueduct to pump wells 2, 3 and 4	3.015
Aqueduct to Lardner's Point Pumping Station No. 1	1.984

The total loss of head between the clear water basin at Torresdale and pump wells at Lardner's Point, when the conduit is delivering 300,000,000 gallons per day, is estimated at 9.25 feet.

To prevent the tunnel from becoming air bound it is graded upwards nine inches per 1,000 feet from Shaft No. 1, Torresdale, to Shaft No. 11, Lardner's Point. Air which may be carried down Shaft No. 1 will either be carried into the tunnel or rise through the water in the shaft. Such air as may be carried into the tunnel will flow with the water and be vented at Shaft No. 11, the upward inclination of the tunnel from the influent to the effluent shaft preventing the accumulation of air, which might be a cause of interference with the operation of a horizontal tunnel. Should there ever be any indications of air sticking, as it were, in the conduit, it is believed that it can readily be removed by increasing the speed of the pumping machinery at Lardner's Point, lowering the level of water temporarily in the pump wells, and creating an increased velocity of flow through the conduit until the air is removed. The conditions under which the water is conducted to the influent shaft, and the upward gradient of the tunnel from the influent to the effluent shafts, are thought to be effectual safeguards against the introduction of any considerable quantity of air into the conduit, or of any reduction of its capacity by the accumulation of air at any point along the roof

Character of Materials on the Line of Work.

The only deep rock operations from which information could be obtained upon the probable character of the material to be encountered in driving the shafts and headings for the northerly end of the conduit are found near the county prison, north of Pennypack Creek. Here the rock excavation in the deep quarry is very hard, with few seams or fissures, and a small

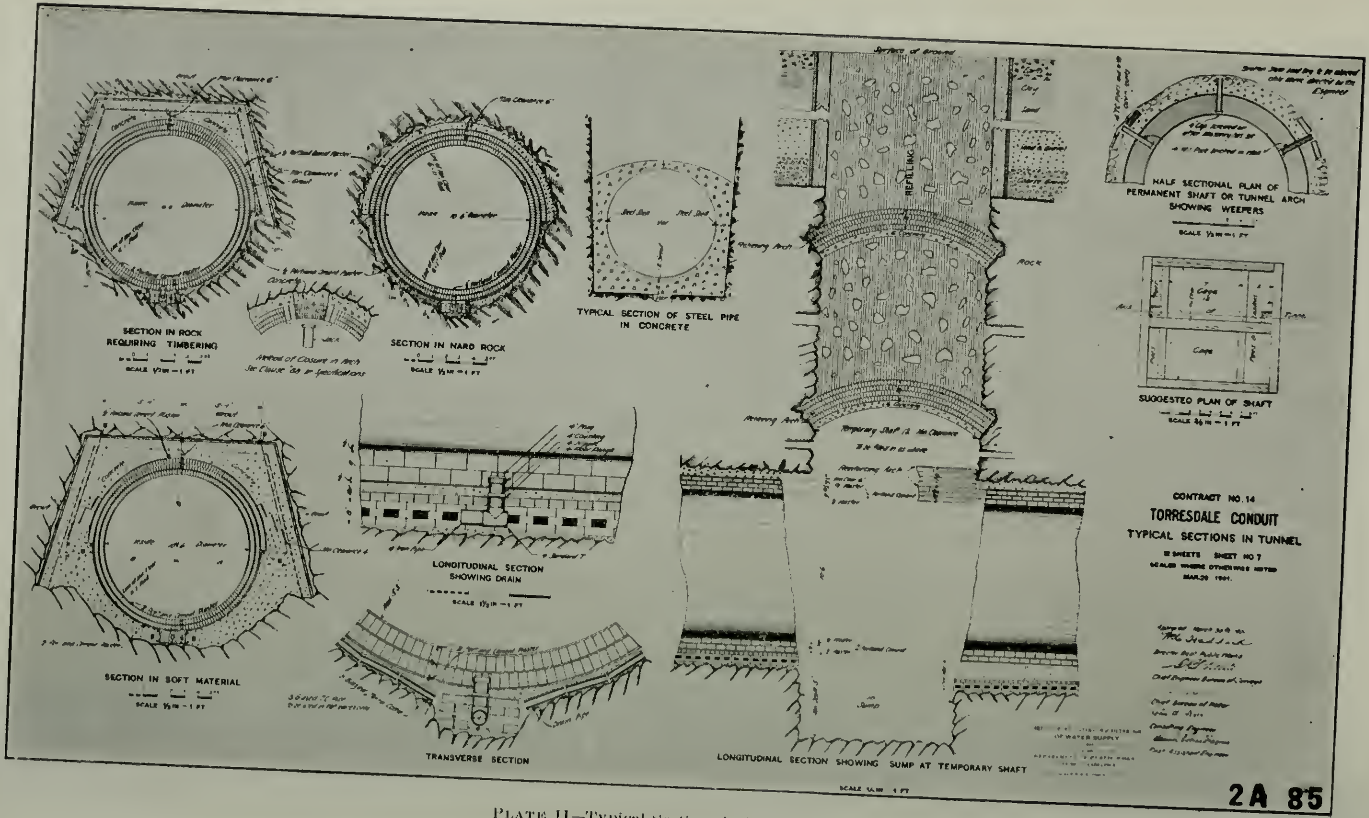
SECTION IN ROCK REQUIRING TIMBERING
SCALE ½ IN = 1 FT
Method of Closure in Arch
See Clause 88 in Specifications
SECTION IN HARD ROCK
SCALE ½ IN = 1 FT
TYPICAL SECTION OF STEEL PIPE IN CONCRETE
Surface of Ground
Clay
Sand
REFILLING
Rock
Temporary Shaft
HALF SECTIONAL PLAN OF PERMANENT SHAFT OR TUNNEL ARCH SHOWING WEEPERS
SCALE ½ IN = 1 FT
Cage
SUGGESTED PLAN OF SHAFT
SCALE ¼ IN = 1 FT
SECTION IN SOFT MATERIAL
SCALE ½ IN = 1 FT
LONGITUDINAL SECTION SHOWING DRAIN
SCALE 1½ IN = 1 FT
TRANSVERSE SECTION
Drain Pipe
Sump
LONGITUDINAL SECTION SHOWING SUMP AT TEMPORARY SHAFT
CONTRACT NO. 14
TORRESDALE CONDUIT
TYPICAL SECTIONS IN TUNNEL
SHEET NO 7
SCALES WHERE OTHERWISE NOTED
MAR. 20 1901.
Director Dept. Public Works
Chief Engineer Bureau of Surveys
Chief Bureau of Water
Consulting Engineer
2A 85

Plate II—Typical Sections in Tunnel.

amount of water, and the typical sections showing excavation for the conduit in hard rock were partially based on this information.

The experience with the conduit confirmed the diamond drill borings, which showed that the character of the rock in the quarry is not maintained for the whole length of the work, and that a great change in the hardness and stability of material takes place in going from the north to the south end. The treacherous material, however, is not continuous, but occurs in reaches of the work, sometimes being abreast of and sometimes crossing the line of the tunnel diagonally.

The diamond drill borings which preceded the preparation of the detail plan indicated the varying character of the rock, but the rapidity with which some of the material would deteriorate upon contact with the air in the tunnel was not fully suspected in advance.

Operations on the conduit were conducted from nine working and two permanent (end) shafts. All shafts were lined to the solid rock. The working, as well as the permanent, shafts were constructed with steel shells sunk into hard rock and sealed, the interior being lined with an eighteen ring of hard-burned stretcher brick laid in cement mortar in the permanent shafts, and a nine inch ring in the working shafts. The sinking and lining of the steel shells for the end shafts was much more carefully executed that it was for the working shafts, because the latter, upon completion of the work, were closed with brick arches continuous with the arch of the tunnel, above which were constructed in each shaft two relieving arches to take a part of the weight of the backfill of the shaft off the arch of the conduit. From the arch of the conduit to ground level the working shafts were solidly backfilled with selected materials.

About ninety-one per cent. of the entire tunnel excavation was in hornblendic and biotite gneiss rock, which required no timber to support the roof. In the north end the rock was very good, but the flow of water, as will be noticed later, was large enough to render it a matter of concern to the contractor and interfered with the lining of the tunnel. Between Shafts Nos. 4 and 7, the rock was of excellent quality, and the flow of water not enough to hinder the work.

Between Shafts Nos. 8 and 9, and in the north heading of

Shaft No. 8, the micaceous rock was very rotten and treacherous, and required heavy and close timbering to prevent dangerous falls. In all such localities the thickness of the arch was increased to four or five rings of brickwork.

Excepting where falls in the roof occurred, the rough diameter of the excavation, heading and bench, is about fourteen feet.

For several hundred feet in the north heading of Shaft No. 9, under the Disston Saw Works, the collar beams and posts supporting the roof abut against each other to prevent dangerous falls and possible injury to valuable surface structures. The placing of this timber not only delayed the progress of the excavation, but naturally occasioned great loss of time in its removal in part, and in placing the brick arch and the concrete packing above and around it.

In carrying forward the arch, for nearly sixty per cent. of the total length enough water was encountered dripping from the rock to make it almost impossible to insure proper setting of the mortar joints excepting the water was wholly excluded from the back of the brickwork, and in order to prevent this, wherever wet roof was met, tar paper in two layers from springing line to springing line of the arch was used to exclude the water until the mortar had set. It was not thought that the tar paper would be a permanent protection in this respect, but experience demonstrated that it could be relied upon to exclude the water for many days, during which time the mortar in the brickwork had sufficient time to harden.

In strengthening Shaft No. 7 as originally sunk and lined, while the contractor insisted that it was perfectly secure for his work, it was not thought that it was entirely safe, either for the contractor's men or for the employees of the City, and in order to guard against any risk from inflows of water from the Delaware River, which, aside from the possible accidents to men employed in the shaft or in the headings driven, would have occasioned a very serious delay in recovering the shaft or in driving a new one, it was decided to reinforce with a ring of concrete from twelve to eighteen inches thick, a portion of the shaft, beginning eleven feet above the shoe of the steel shell, and continuing down thirty-eight feet six inches into the excavated rock.

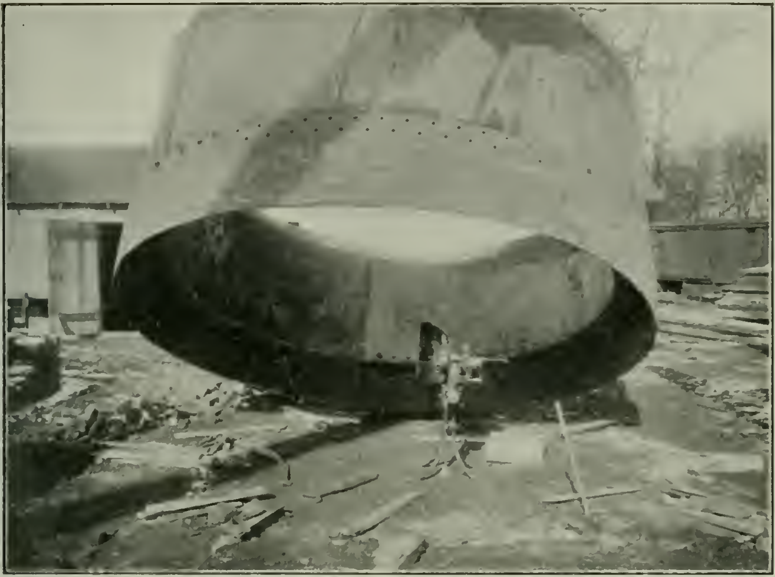

PLATE III.—Cast Iron Shoe and Section of Steel Shell in Temporary Shafts

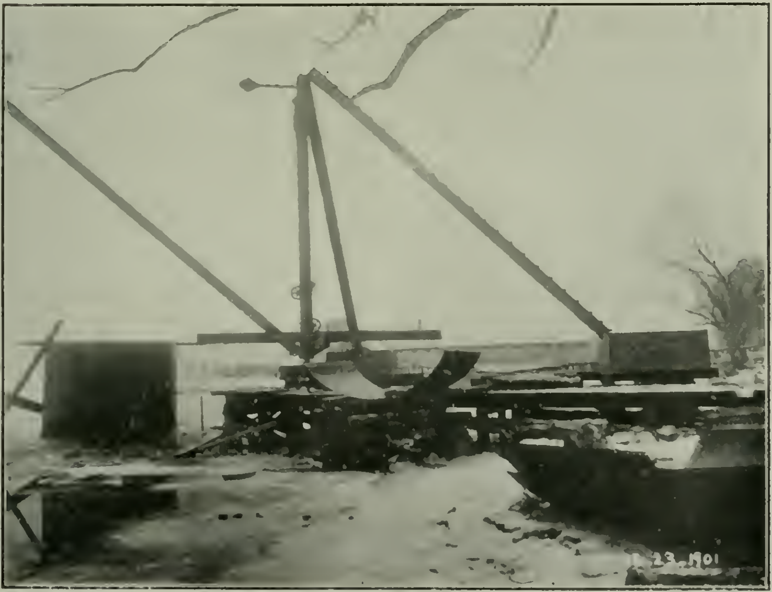

PLATE IV.—Head of Steel Shell, Shaft No. 7.

In the original plans for the work it was thought that the bends at the ends of Shafts Nos. 1 and 11 could be turned of brick, but study of the matter during progress of lining the tunnel led to the belief that these bends would be smoother and more uniform in section, and more stable, if constructed of concrete than if the attempt was made to line them with brick. Forms were then built, bolted, and doweled together, and carefully tested for dimensions at the surface of the ground, and then taken apart and set up in their true positions at the bottom of the shafts, around which was placed concrete entirely filling the spaces between the forms and the ragged rock around the excavation.

AIR COMPRESSORS, ETC.

Compressed air for the different sections of the work was furnished as follows:

Section 1: Shafts Nos. 1, 2, 3 and 4, by a Rand single stage compressor, with twenty-four inch air cylinder, twenty-four inch steam cylinder, thirty inch stroke, running at eighty-three revolutions per minute, located at Shaft No. 3, on the House of Correction grounds.

Section 2: Shafts 5 and 6, by two Ingersoll-Sergeant single stage compressors, with twenty-two and one-quarter inch air cylinders, twenty-two inch steam cylinders, twenty-four inch stroke, running at ninety-four revolutions per minute, located at the intersection of Eugene and Bleigh Streets.

Section 3: Shafts 7 and 8, by one Sullivan compound, or two stage compressor, with fourteen inch and twenty-two inch air cylinders, fourteen inch and twenty-two inch steam cylinders, all twenty-four inch stroke, running at 110 revolutions per minute. Located in the Pennsylvania Railroad yard at the foot of Disston Street, Tacony.

Section 4: Shafts Nos. 9, 10 and 11, by one Rand duplex compressor, with twenty inch air cylinder, twenty inch steam cylinder, thirty inch stroke, running at eighty-seven revolutions per minute; and one Ingersoll-Sergeant single stage compressor, with twelve inch air cylinder, twelve and one-quarter inch steam cylinder, and fourteen inch stroke, running at 155 revolutions per minute. Located at the intersection of Delaware Avenue and Levick Street.

The free air capacity provided for the different sections was as follows:

Section	1	2,670 cubic feet per minute.		
"	2	960	"	"
"	3	1,160	"	"
"	4	2,185	"	"

Steam was supplied to the machine from locomotive and return tubular boilers, working at pressures ranging from ninety to one hundred pounds by gauge, and compressed air was used at from seventy to eighty pounds pressure by gauge.

Head houses were built over each shaft, excepting Shaft No. 11, where the elevation of muck and lowering of men and materials, was done by a swinging boom derrick and dumping buckets. All head houses were provided with cages fitted with safety catches, upon which narrow-gauge dump cars were run for raising muck and lowering materials.

All rock drills and some of the pumps were operated by compressed air, the exhaust from which served to ventilate the headings and shafts.

MEETING OF HEADINGS.

In the following table are given the dates of meeting of headings, errors of line, errors of grade, and horizontal distance between shafts from which the operations were conducted.

Plumb-bobs and a Buff and Berger plunging transit both were used to project the line of the work from the surface of the ground to the bottom of the shaft. The large error of line at the meeting of the headings between shafts Nos. 5 and 6, is due to the use on this section of the transit only in projecting the surface line down Shaft No. 5.

The error of line in the meeting of Shafts Nos. 3 and 4 was due to the same cause, Shaft No. 3 being too much out of plumb to admit of using the plumb-bob.

Between Shafts	Date	Time	Error in Line Inches	Error in Grade Feet	Distance between Shafts Feet
Nos. 1-2	July 21,'03.	6.00 P.M.	5-$\frac{1}{4}$	.007	1351
" 2-3	April 12,'03.	7.00 A.M.	$\frac{5}{8}$	.0312	1330
" 3-4	Feb. 7,'03.	5.30 P.M.	4	.0208	1244
" 4-5	April 27,'03.	7.00 P.M.	$\frac{1}{2}$	.004	1640
" 5-6	Nov. 9,'02.	4.00 A.M.	7	.0104	1353
" 6-7	May 23,'03.	3.00 A.M.	1-$\frac{1}{2}$	.020	1562
" 7-8	May 13,'03.	6.00 P.M.	$\frac{1}{8}$	.013	1635
" 8-9	June 6,'03.	12.00 M.	$\frac{3}{4}$	.014	1580
" 9-10	Oct. 11,'02.	2.15 P.M.	$\frac{1}{4}$	.0104	1110
" 10-11	Dec. 13,'02.	2.00 P.M.	1-$\frac{3}{4}$	.0312	1003

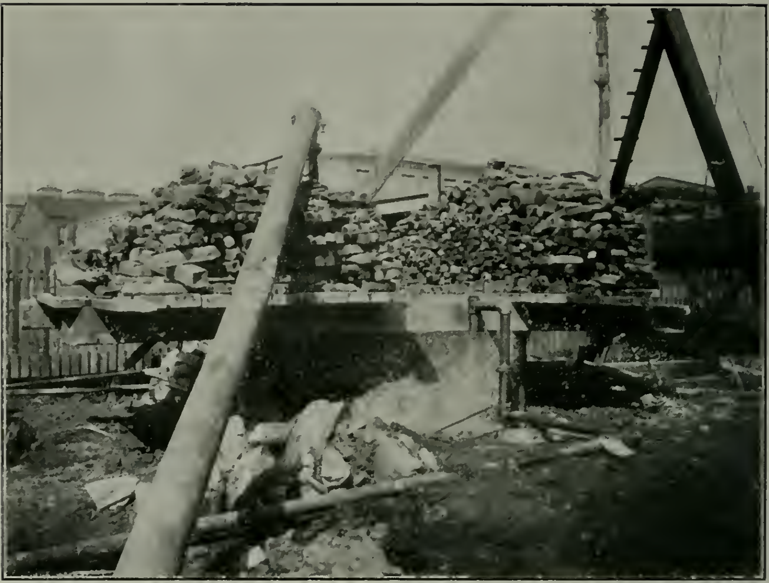

Plate V.—Sinking Steel Shell, Shaft No. 9.

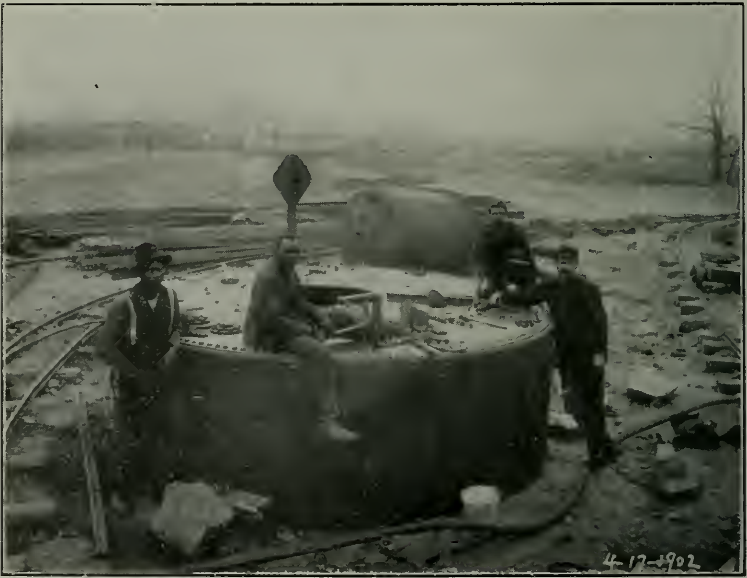

Plate VI—Diaphgram for Air Lock, Shaft No. 2.

HISTORY OF THE CONTRACT.

The history of the contract is shown in the following table, including the assumed date of completion:

Date of letting	May 28, 1901.
Date of award	August 28, 1901.
Date of contract	October 4, 1901.
Date of revision of paragraphs 24 and 30 of the specifications	October 21, 1901.
Time limit for completion of work	Nine (9) months.
Notice to begin work	January 9, 1902.
Expiration of contract time	October 9, 1902.
Date of completion	April 23, 1904.
Default in time of completion	424 working days.

There was at no time any indication of lack of energy on the part of the contractor to forward the work to the earliest possible completion. From its inception, about December 1st, 1901, to April 23rd, 1904, at no time was the work even temporarily abandoned, although certain of the shafts, like Shaft No. 4 and Shaft No. 7, were, for reasons hereafter to be explained, abandoned for short lengths of time.

The first cause of delay was due to the decision of the City to deepen all shafts by ten feet, which conclusion was reached March 25, 1902, after Shaft No. 9 had been driven to the line of the tunnel. The terms of the contract provided that the first Shaft (No. 9), which seemed to show from the diamond drill borings the poorest material in the rock, should be driven in advance of the other shafts to the line of the tunnel, in order to determine whether the center line, as shown by the original plans, could be safely adopted for the prosecution of the work. Upon sinking this shaft to the elevation originally shown, the material was found to be of such treacherous character that it was determined to lower the center line of the tunnel everywhere by ten feet. Although several of the other shafts were in progress simultaneously with Shaft No. 9, they were not advanced as rapidly as this shaft for the reason given.

In the construction of Shaft No. 7, in Eugene Street, between Cottman and Princeton Streets, and about opposite St. Vincent's Orphan Asylum, when the steel shell reached the rock, and the work of driving into the rock was begun, it was regarded as unsafe for use, and work was temporarily suspended upon orders of the City, until such time as the shaft might be made safe for the use of the Engineers and Inspectors, as well as the men in the employ of the contractor. Nearly one month's time was lost between the date when the work was suspended and the operations again resumed.

In carrying forward the north heading from Shaft No. 9, a soft seam, consisting apparently of a mixture of plastic clay and rotten, micaceous rock, was encountered, requiring very careful and constant timbering of the work as the heading advanced. From November 6th to December 26th, 1902, the rate of progress was less than twelve inches per day. From January 1st to February 5th, 1903, the rate of progress represented less than twelve inches a day; the normal rate of progress throughout the work was slightly over two feet per day.

On February 5th, 1902, owing to an accident, Shaft No. 4 was so seriously damaged that notwithstanding vigorous efforts were made to reclaim it, it was finally abandoned on March 17th, 1902, at a depth of about fifty feet below ground level. The second shaft was then located about 100 feet south of original Shaft No. 4, and driven down to the line of the tunnel without any further trouble at this station.

Owing to the inflow of water, an attempt was made to use an air lock on Shaft No. 2, but after trial of about six weeks, this was removed, and progress continued to the end of the work in the open-shaft and headings.

During the coal strike in 1902, serious difficulty was encountered in securing enough coal to keep the machinery running at all the shafts, and especially between Shafts Nos. 1 and 8 there were times when the supply of fuel was so low as to prevent the working of the usual double shift of men. In due time this trouble was remedied through the kindly aid of the officials of the Pennsylvania Railroad.

Considering the very large amount of brick required for lining the permanent shafts and tunnel (over 9,700,000) considerable difficulty was experienced in getting brick of a satisfactory quality. Several cargoes of brick were offered for use and rejected entirely by reason of the very large percentage found unsuitable upon inspection, and the contractor was, therefore, directed to procure bricks from manufacturers whose general run of material met the requirements of "sound, straight, hard-burned brick, uniform in size and structure, and with true even

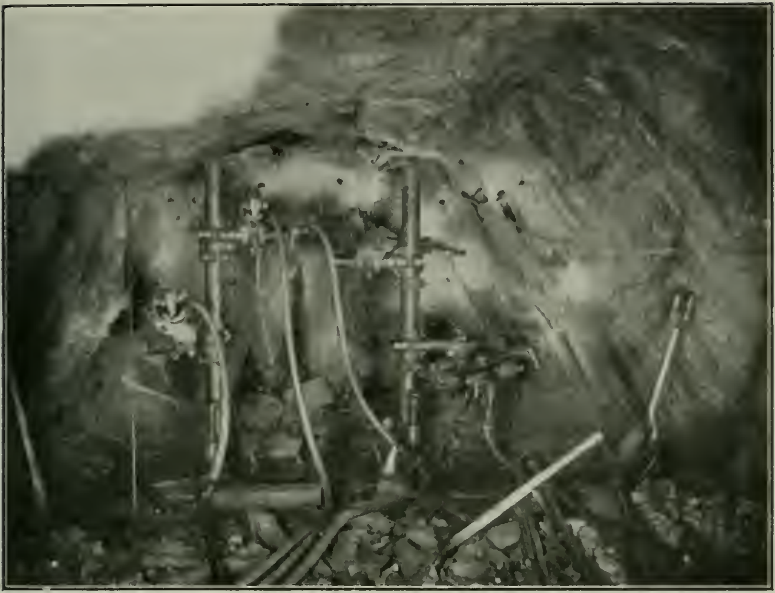

PLATE VII.—Method of Drilling in Hard Rock.

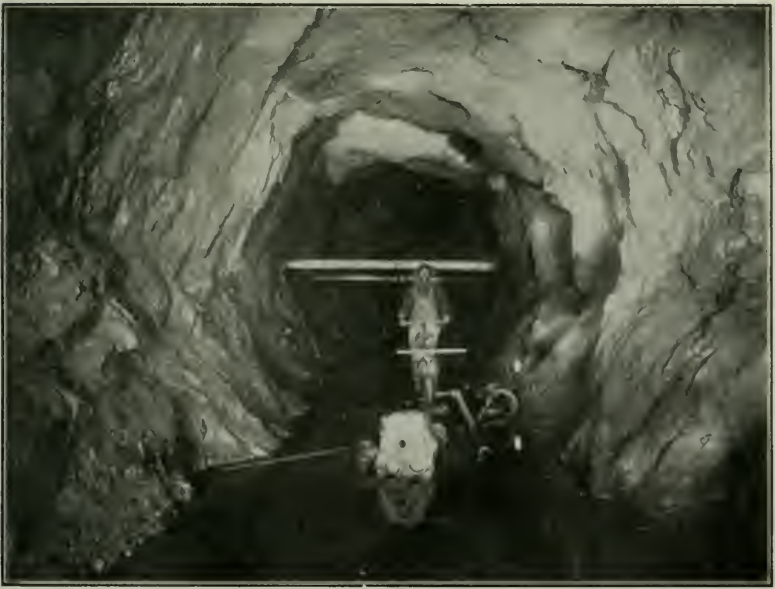

PLATE VIII.—Excavation in Hard Rock, South Heading, Shaft No. 1

faces." In fact, it was not possible to get the large quantity of brick required in the lining of the tunnel and permanent shafts from one manufacturer, and to meet the conditions, excepting as to size, and avoid delay, two sizes of brick were used. The first brickwork was placed in Section 4, January 3, 1903.

PLASTERING BRICKWORK.

Concerning the one-half inch coat of Portland cement plaster on the face of the brickwork in the conduit, which was omitted because it was found impossible to make it continuous from end to end of the conduit by reason of the dampness of the brickwork in the arch, there is some doubt in my mind whether any decided advantage in the smoothness of the interior of the conduit for a great length of time would be accomplished by the plaster coating. The experience of Mr. James M. Gale, Engineer in charge of the Waterworks of Glasgow, who built the second aqueduct which brings the water from Loch Katrine to the Mugdock Reservoir, has raised a doubt of the advisability of plastering a conduit intended to carry a reasonably soft water, such as is the water from the Delaware River. The solvent action of soft water upon the uncombined lime in Portland cement mortar is well known, and it is possible that in due time the Delaware River water would have pitted and roughened the surface of the plaster lining so as to render it less smooth than well laid brickwork with struck and trimmed joints. In the construction of the invert of the tunnel and in the construction of the rings in the shafts, all joints were struck. This, of course, was not possible in the construction of the brickwork of the arch, but upon removing the centers and after the mortar had set, all excess mortar in the soffit joints was carefully trimmed away from end to end of the conduit. While it is true that, at joints in the lining of the conduit, there is some noticeable irregularity or lack of smoothness in the brickwork, this represents a very small portion of the 14,000 feet of conduit, and by far the larger percentage of the shafts and tunnel consists of brickwork as smooth as any that I have ever seen laid in sewer work where the operations were conducted in open cut, and under much more favorable conditions for neat bricklaying than were found in the conduit.

When it became evident that the plastering could not be made to stick to the brickwork of the arch, about twenty-one per cent. of the total length of arch had been placed, and orders were then issued to the Contractor and the Engineers and Inspectors in charge of the lining, to exercise especial care in building the arch true to line and radius, in view of the probability that the plastering of the brickwork could not be accomplished and that the face of the brick lining would be, upon completion, the wetted perimeter. At least seventy-nine per cent. of the soffit of the arch is as true and smooth as the lining of the invert which was laid to templets with struck joints.

The only real objection to the omission of the cement plastering was the possible reduction of carrying capacity, and if experience should show this to be the result, it would then assume a serious phase. But directly it was demonstrated that the plastering could not be successfully and continuously applied to the arch, extra precautions were taken in laying the brickwork, and upon drawing the centering all excess mortar in the joints was chipped away flush with the face of the arch.

Investigations of the value of "n" in the Kutter formula for flow of water in closed channels, of plastered and unplastered brickwork, seemed to show that "n" $= .013$ could safely be applied to the unplastered brickwork of the conduit, and if this conclusion is well founded, it should have the full capacity intended, with unplastered arch ten feet seven inches in diameter. As a rule, the invert was a very smooth piece of brickwork, and it is not thought that plastering would have materially improved this in flowing function.

PORTLAND CEMENT AND CONCRETE.

Only Portland cement was used in all parts of the work, as follows:

24,162	barrels of	Star Bonneville
9,650	"	Lehigh
675	"	Saturn
450	"	Giant
34,937	"	Total

Concrete was mixed in the following proportions:

For the cradle of invert and packing of arch:
1 part cement
3 parts sand
5 parts broken stone ballast.

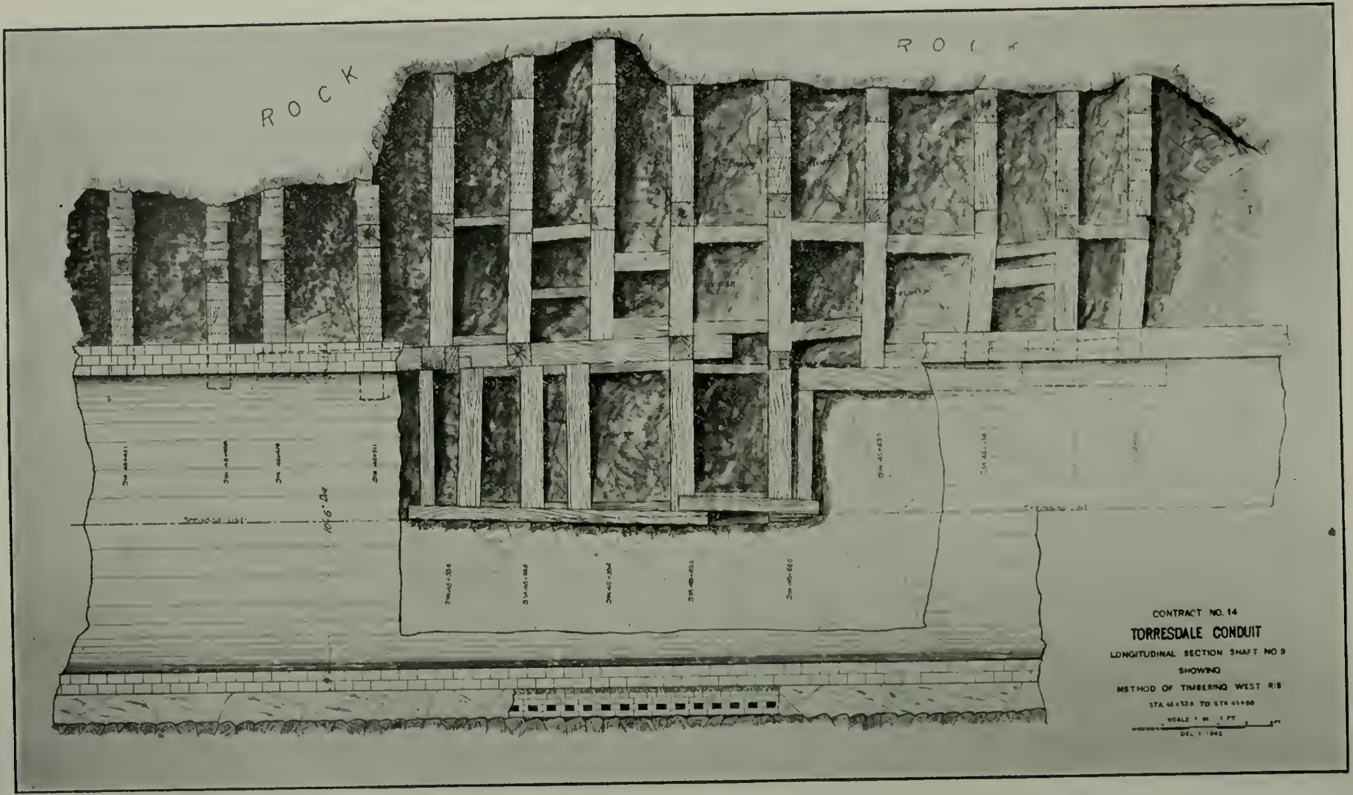

PLATE IX.—Timbering in Soft Rock, North Heading, Shaft No. 8.

For the bends of Shafts Nos. 1 and 11:

1 part cement
1½ parts sand
1½ parts limestone screenings
5 parts broken stone ballast.

Face work of bends:

1 part cement
1 part sand
1 part limestone screenings.

CONCRETE CUBES.

During the progress of the work 418 concrete cubes were made as samples of the material used in the construction of the cradle and of the arch, and these were broken after 60, 90, 120 days, and six months; and the very best concrete, as shown by the compression tests, used anywhere in the work of the Improvement, Extension, and Filtration of the Water Supply, was used by the Contractor for Contract No. 14, some of the cubes exceeding 5,000 pounds per square inch in the crushing test.

COST OF WORK.

Contract price		$1,274,000.00
Extras authorized by City	$68,505.33	
Deduct scrap steel sold and work not performed	546.60	67,958.73
Total Cost		$1,341,958.73
From which deduct plastering not placed		20,735.54
Difference		$1,321,223.19

The probable cost of the work to the contractor from records made of materials furnished and work performed was $1,306,186.62, or $93.10 per linear foot.

The quantities of materials as per original estimate, prior to making of contract, and as actually performed, are shown in the following table:

1 Items	2 Original Quantities From Plans	3 Quantities Actually Performed	4 Increase Over Original Estimate	5 Additional Quantities Not Included in Cols. 3, 4, Ordered as Extras
Excavation—				
Tunnel, cubic yards	83,670	89,366.90	5,696.9	....
Shaft, " "	5,632	7,425.00	1,793.0	21.0
Concrete " "	22,381	24,058.00	1,677.0	3,278.8
Brick Masonry, cu. yds.	18,802	18,360.45	....	1,145.7
Plastering, linear feet	14,058	....	....	....
Cast-iron, lbs.	117,640	128,578.00	10,938.0	....
Steel "	346,374	353,205.00	6,831.0	....
Clay for puddle, cu. yds.	....	....	....	94.5
Tar paper, single thickness square feet	....	....	.. ....	619,000.0

The additional shaft excavation was authorized under the provision of the contract which permitted a lowering of the center line of tunnel if found advisable so to do upon sinking Shaft No. 9, which shaft was first driven to the line of tunnel.

The clay puddle was used over the arch of the closures for the working shafts to render these watertight while the mortar in the brick was setting. Two thicknesses of 3-ply tar paper, not included in the original plans, were used over the brick arch where this was laid under wet roof.

ADDITION TO QUANTITIES.

In addition to the above statement of quantities of work performed, there was used, but not incorporated as such in the estimates, the following materials:

34,937	barrels of cement,
9,703,700	bricks,
12,688	cubic yards sand,
16,725	cubic yards ballast,
11,184	linear feet of 6-in. terra-cotta pipe,
138,814	feet B. M. timber.

In apportioning the lump sum bid for the several items entering into the construction of the work, for the purpose of current estimates, the following unit prices were used:

Excavation in tunnel	$ 7.90	per cu. yd.
Excavation in shaft	19.00	" "
Concrete	9.00	" "
Brickwork	13.00	" "
Plastering interior of brick lining	1.475	per linear foot
Castings	.07	per lb.
Steel work	.09	"

COST OF TUNNEL COMPARED TO PIPE LINE.

Upon the assumption that the cost of the conduit is based on the limit of contract, viz., $1,350,000.00, the cost per linear foot becomes:

$$\frac{1,350,000}{14,030}=\$96.22$$

Relating this to the cost of twelve equivalent lines of 48-inch cast-iron pipe aggregating 38.8 miles, viz., 38.8 × 5,280 × $16.00 = $3,277,824.

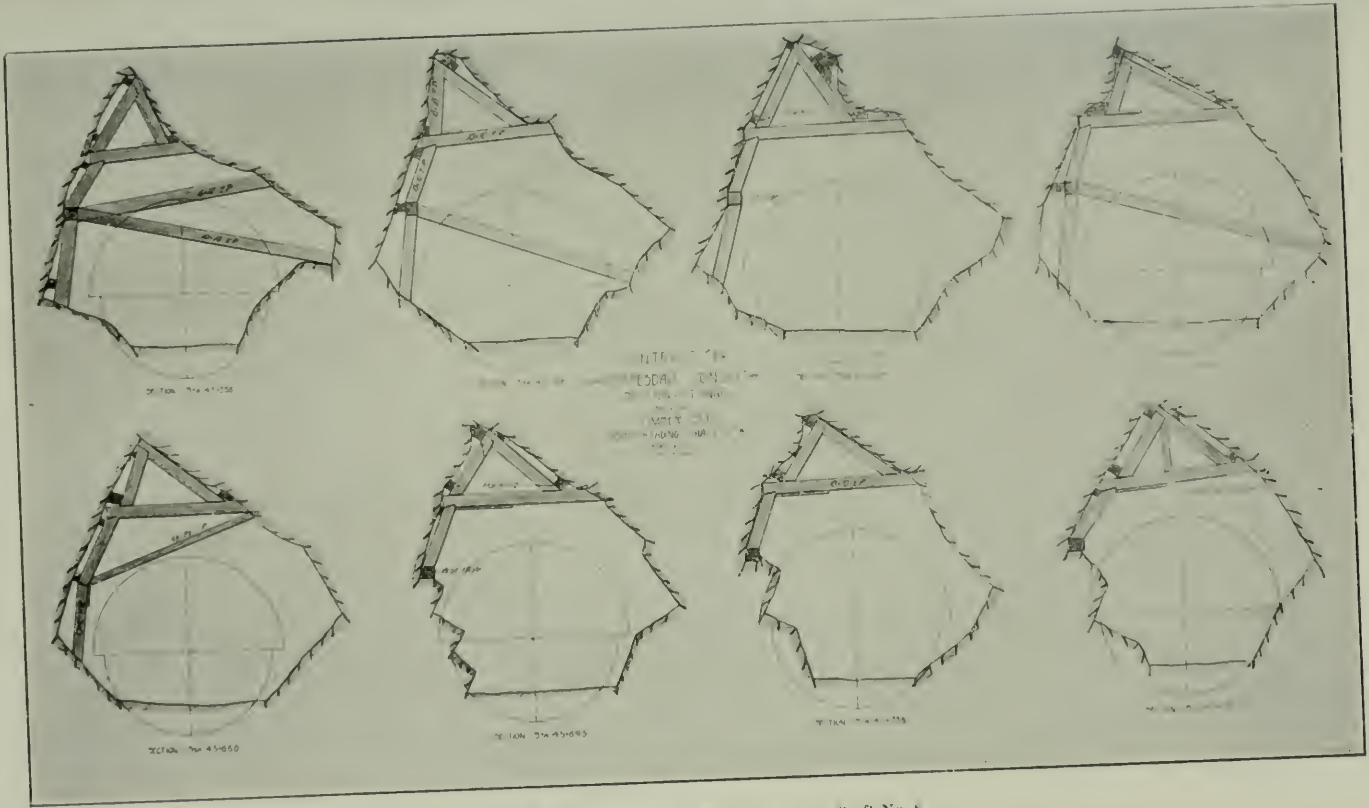

PLATE X.—Timber Sets in North Heading, Shaft No. 8.

Or, reduced to the length of the tunnel, the cost per linear foot becomes:

$$\frac{3,277,824}{14,030} = \$233.62$$

FATAL ACCIDENTS.

During the construction of the conduit fourteen lives were lost, as follows:

Shaft No. 1.—November 20, 1902—One man killed by the fall of a fragment of rock from the side of the shaft.

Shaft No. 2.—June 2, 1902—Foreman killed while riding down the shaft on a pump which was being lowered to position at the bottom of the shaft, by a piece of pipe which became disconnected and fell.

Shaft No. 3.—August 14, 1902—The pump man at foot of shaft killed by dropping of a drill from the cage in the shaft.

January 10, 1903—One man fatally burned in a shack fired by an explosion of the dynamite stored in the magazine.

Shaft No. 4.—July 31, 1902—One man killed by being struck by the boom of derrick and knocked into shaft.

Shaft No. 7.—May 20 and May 21, 1902—Two men fatally overcome by powder fumes in the heading.

Shaft No. 9.—April 30, 1902—Three men killed at one time by the tipping of a bucket in which they were being drawn up out of the shaft. The hoisting engine developed some trouble, and just as the boom of the derrick was being swung clear of the shaft, the hoisting rope slipped and bucket struck on the upper edge of the steel shell and dumped the men into the shaft.

Shaft No. 10.—April 5, 1902—One man was killed by being crushed between the side of the shaft and the discharge pipe of a pump which was being lowered in the shaft.

Shaft No. 10.—December 2, 1902—One man killed by being hit in the head by a fragment of rock from a blast fired in the south heading 400 feet distant.

Shaft No. 10.—December 4, 1902—One mall killed by fall of rock from the roof in the south heading.

Pennypack Creek.—Between Shafts Nos. 1 and 2, man drowned by leaping from the transfer boat, which he supposed was sinking.

ESTIMATED CARRYING CAPACITY.

Data upon the actual flowing capacity of large brick lined conduits under pressure is very meagre, but with the loss of head between Shaft No. 1, at Torresdale, and Shaft No. 11, at Lardner's Point, of 8.6 feet, it is assumed that the conduit will have a carrying capacity of 300,000,000 gallons per day of twenty-four hours.

By Kutter's formula, with "n" taken at 0.013, the capacity for the given loss of head will be:

$$V = 136{,}1\sqrt{2.645 \times .000616} = 5.484 \text{ feet.}$$

$$Q = 5.484 \times 87.97 = 482.427 \text{ cubic feet.}$$

$$G = \frac{482.427}{1.5472} = 311.8 \text{ million gallons per day.}$$

By Lampe's formula:

$$V = 167.89\, r^{.684} \times s^{.555} = 5.455 \text{ feet;}$$

$$Q = 5.455 \times 87.97 = 478.987 \text{ cubic feet;}$$

$$G = \frac{478.987}{1.5472} = 309.6 \text{ million gallons per day.}$$

The capacity, of course, can be increased by lowering the level in the pump wells at Lardner's Point, and increasing the loss of head in the conduit.

The cubic contents of the conduit, taken to the normal level of ground water, 197.00 T. D., is 9,253,932 gallons, and the time required for water to flow from Shaft No. 1 to Shaft No. 11, when the conduit is delivering 300,000,000 gallons per day will be about forty-four minutes.

COMPARISON OF CONDUIT AND EQUIVALENT SYSTEM OF 48-INCH GRAVITY CAST-IRON PIPES.

In order to balance the carrying capacity of the Torresdale Conduit with a system of cast-iron gravity pipe with the same loss of head, it will require twelve lines of 48-inch cast-iron pipe of an average length of 17,100 feet for each line, or a total length of 38.8 miles.

Experience has shown that a leakage of 8,630 gallons per mile per day of twenty-four hours in a line of 48-inch cast-iron pipe, operating under a pressure of fifty pounds per square

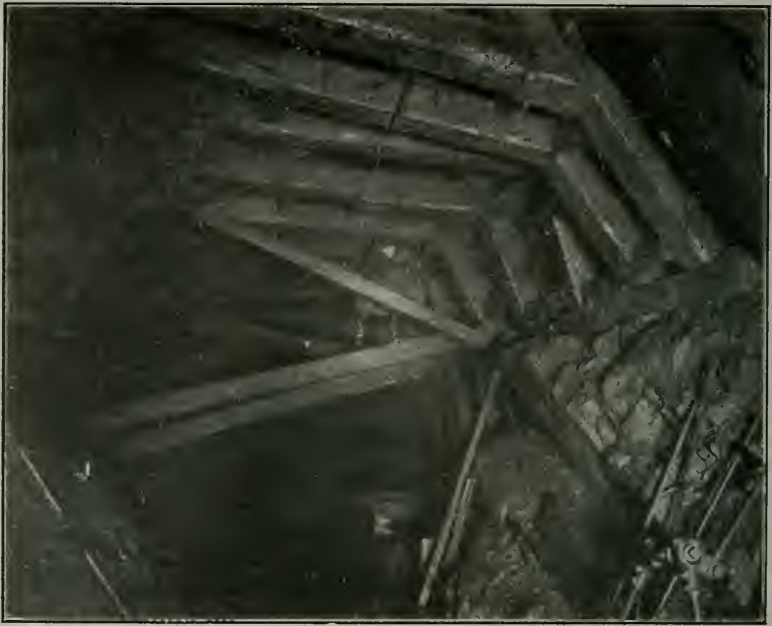

Plate XI.—Timbering, Shaft No. 8, North Heading.

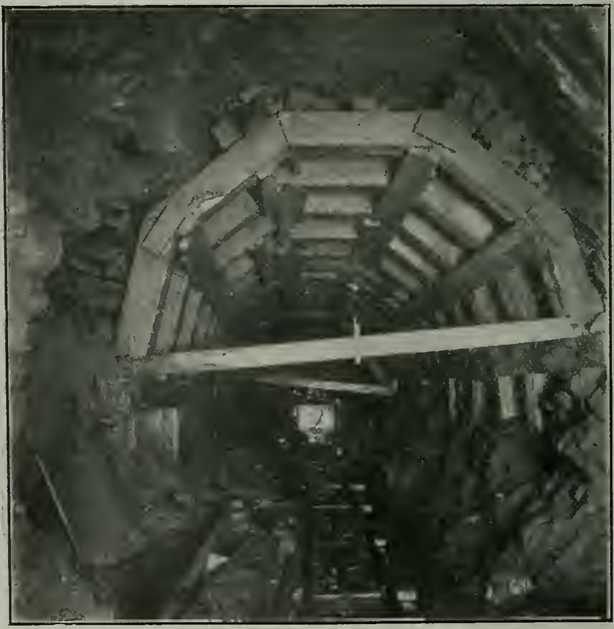

Plate XII.—Timbering, Shaft No. 9, South Heading.

inch, is allowable under all ordinary conditions. The head required for a flow of 25,000,000 gallons per day through each of the twelve lines of 48-inch pipe mentioned is 10.3 feet; and prorating the leakage on the square roots of the heads, the allowable leakage for 38.8 miles of 48-inch cast-iron pipe having the same capacity as the Torresdale Conduit, amounts to 100,000 gallons per day of twenty-four hours.

The cost of the cast iron gravity conduit would have been, at the prices prevailing when the conduit was let by contract, about $3,278,000.00, or $1,928,000.00 more than the cost of the structure as built.

The interest charges alone on the difference of cost at 3½ per cent. would have been $67,474.00, while the annual charge due to the probable loss of 200,000 gallons of filtered water per day at $5.00 for filtration and low service pumpage, and $3.84 for interest charges on the Torresdale works, will amount to $6,453.20.

But it has been shown that an allowance of 100,000 gallons per day for the leakage of the cast iron pipes is reasonable, and hence of the annual value of water lost, one-half only should be charged against the conduit, or $3,226.60; about one-twentieth of the interest charges on the increased cost of cast iron gravity pipe lines.

Examination of the Conduit.

After closing the last two working shafts, Nos. 2 and 7, early in April, 1904, and removing the pumping machinery from Shaft No. 1, daily observations were taken from April 8th to the 18th on the rise of water in the tunnel and end shafts.

After plotting the elevations of water level and corresponding leakage it was found that the leakage was greater than was anticipated at the time of removal of the pumps, and more than could be readily accounted for, provided the sump at Shaft No. 1 and all open weepers, had been properly closed.

The contractor's attention was promptly called to the apparent excessive leakage, and after full consideration of the matter it was finally decided to pump out the conduit, make an examination of the interior, and correct any defects or oversights of the contractor's work which such examination might reveal.

THE RESULTS OF EXAMINATION.

After considerable delay in making the necessary arrangements for head house, boilers, and pump to empty the conduit, the work of pumping out was started August 13, 1904, using for this purpose at first a No. 8 DeLaval steam turbine, having a rated capacity of 1,200 gallons per minute under 125 feet head, and later a No. 9 and a No. 11 Cameron shaft sinking pumps. The No. 9 Cameron pump had a capacity of 300 gallons per minute, and the No. 11, Cameron, a capacity of 450 gallons per minute.

The pumps were hung on wire cables from hand winches and chain blocks in such manner that they could be lowered as the water level in the shaft was reduced; and as each pump was lowered by stages in this manner, the three lines of pipe reaching from the ground level to the pumps was increased by adding sections uniformly ten feet in length.

The discharge of the pumps was carried into a tight wooden sluice way and run into a weir box having a width of five feet, a depth of one foot nine inches below the weir crest, and a length of fourteen feet, and provided with the usual screens to smooth the water before it approached the weir, and with a weir having a notch twenty-one inches wide by nine inches deep. The weir was made of brass plate, with sharp edge, set truly plumb, and at right angles to the axis of the weir box, and with the crest level from end to end. The heads on the weir were read by means of an ordinary hook gauge with vernier reading to one-thousandth of a foot, set in a stilling box outside the weir box, and connected with the latter by means of a perforated iron pipe laid across the bottom about three feet up-stream from the weir.

All conditions for accurate measurement of the water pumped from the conduit were carefully observed, the point of the hook gauge being referred to the crest of the weir from day to day by means of a "Y" level and leveling rod.

The same outfit, of course, served not only to measure the rate at which water was being removed from the conduit before it was emptied, but after it was emptied, to gauge the leakage, all of which, of course, was removed from Shaft No. 1 and discharged over the weir.

Observations of the head on the weir, of the level of the

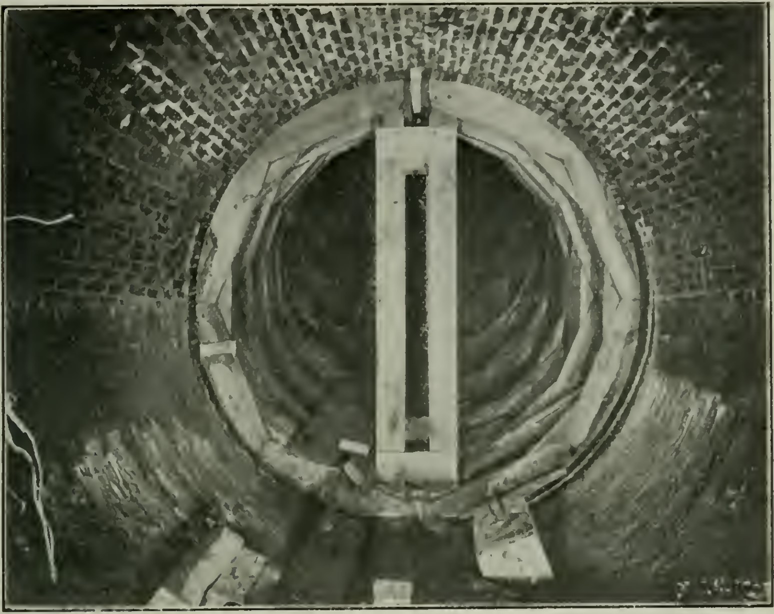

PLATE XIII.—Form for Turning Concrete Bend, Shaft, No. 11.

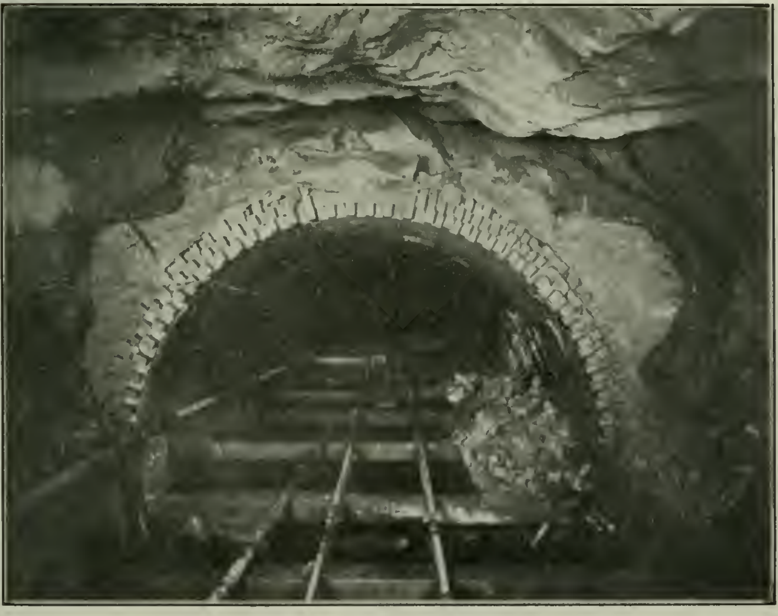

PLATE XIV.—Lining of Tunnel Looking Towards Shaft No. 2.

water in Shaft No. 1, and of the general conduct of the work, were made hourly, night and day, throughout the operations from the time the pump was started on August 13th, 1904, until December 17th, when the pumps and all other material were removed from Shaft No. 1, and preparations made to close the shaft head, and after this until January 12th, at which time the ground water having reached elevation 193.00 T. D., was rising at such a slow rate as to render further observations unnecessary.

The depth and diameter of the shaft rendered all operations for pumping out and repairing the conduit very difficult. After the two Cameron shaft-sinking pumps, and the DeLaval steam turbine, with their steam exhaust and discharge pipes, had been hung, the remaining space for lowering men and materials was too small for a cage or even a bucket, and only about large enough to accommodate a boatswain's chair suspended from the hook of the derrick. I cannot compliment too highly the riggers and engineers in charge of the derrick for their careful work for the period of 132 days of active operations, during which time no serious accident to men or machinery occurred.

October 20th, 1904, the water was lowered in the conduit until the depth over the invert at Shaft No. 1 was such as to permit of an examination being made from end to end, at which time it was discovered that the sumps at Shaft No. 1 and Shaft No. 2 had not been closed. In addition to the open sumps, considerable water was coming into the conduit through a number of large open joints in the brickwork, and from several particularly wet spots in the arch between Shafts No. 8 and No. 11, but by far the largest proportion of leakage was from the two open sumps, as the gaugings later given will show.

CLOSING SUMPS.

The sump at Shaft No. 1 was closed in the following manner:

An opening about eight feet long by five feet wide was cut through the brick invert and concrete cradle for a depth from the center of invert of twenty-four inches. The center of the sump thus formed was further excavated by blasting the rock for a depth of fourteen or fifteen inches to accommodate the suction of the No. 11 Cameron pump, which was arranged to pump the water away from this sump until it was finally closed Over the bottom of the excavation coarse gravel and boulders were carefully spread by hand and leveled for a foundation for the casting or "sump closer." On the gravel was set, and lined and leveled, a flared cast-iron box, measuring six feet, six and one-half inches in length, by three feet three and one-half inches in width over the lower flange, and five feet ten and one-half inches in length, by two feet six and one-half inches in width over the upper flange, with an anchor flange at mid-height having a mean of above dimensions.

The internal dimensions of the box were five feet seven and one-quarter inches long at the bottom, and five feet long at the top, by two feet four and one-half inches wide at the bottom, and one foot eight inches wide at the top. Across the casting at midlength a bridge was cast.

The upper flange was planed and drilled for one inch diameter studs, and the casting was closed by a cover divided at midlength with a sharp "V" shaped groove for lead joint at the junction of the two plates.

The box was everywhere one and one-quarter inch thick, and the cover one and one-half inch thick.

One section of the cover plate was bored, drilled and tapped in the center for a six-inch union flange, and short six-inch nipple with a flange on the top to accommodate the suction of the Cameron pump.

The casting was leveled on the gravel base; the water pumped down to and maintained at the level of the lower flange, and the box concreted in place, leaving, of course, the center open to serve as a sump until the opening was finally closed. After the concrete had set for two weeks, the cover plates were bolted down on white pine gaskets; the "V" opening between the plates caulked with lead and the pump suction reduced in size and set in the six inch riser in one of the cover plates. The riser, upon removal of the pump, was closed with a six-inch flange bolted down on a white-pine gasket.

To bring the water freely from the sides of the sump to the center of the casting, short lengths of old four-inch boiler flues were set in place as the gravel was laid.

When the sump was closed, it was perfectly water-tight. All the work connected with the placing, concreting, and final

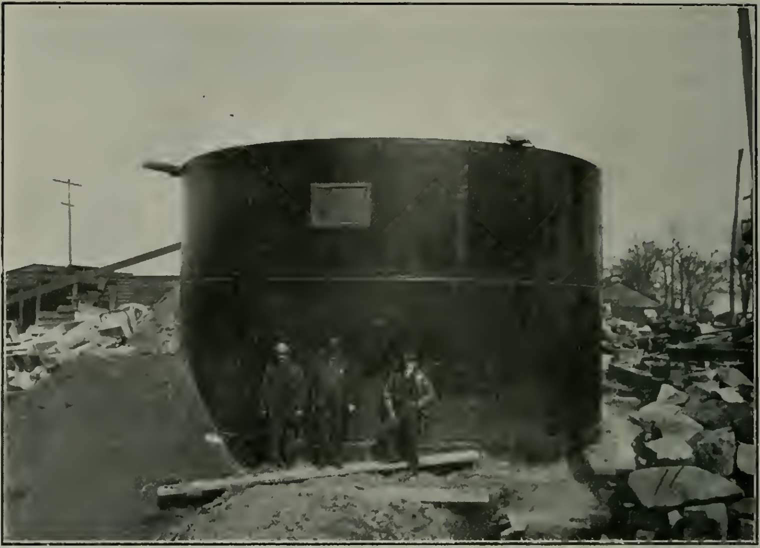

Plate XV.—Top Section of Steel Shell, Shaft No. 11.

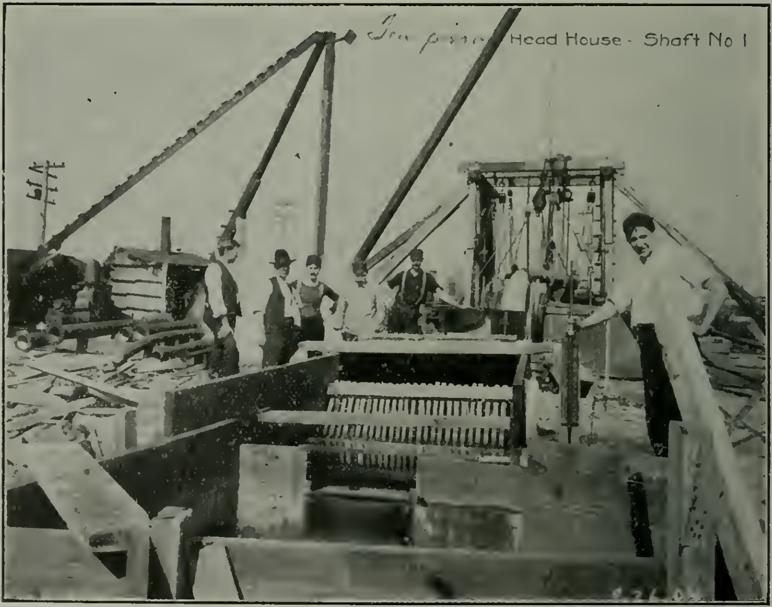

Plate XVI.—Temporary Head House, Shaft, No. 1.

closing of the casting was performed under the supervision of Mr. John E. Powell, Superintendent in charge of repairs.

At the open sump at Shaft No. 2 a different plan was adopted. Here the original plan was to square the opening carefully to the smallest possible dimensions; fill the hole with coarse gravel, set above it on the invert a stout wooden form braced down and made watertight by caulking around the edges, and pump grout into the opening under fifty or sixty pounds' pressure through a two-inch pipe set in the form. In cutting out the hole the workmen misunderstood orders and made the sump large enough to receive the form. This mistake or blunder caused at least two weeks additional work, and largely increased the cost and difficulty of closing the sump.

Several expedients were adopted and failed of the purpose, and finally a No. 4 centrifugal pump of 400 gallons capacity per minute was set up near the sump. An alternating current motor was procured and set up on a temporary timber platform, and belted to the pump, and the current to operate the motor carried in from Shaft No. 1, a distance of 1,400 feet. The suction of the pump was then set in the bottom of the sump, and the discharge set in a sluice box which delivered the water north of a temporary sand bag and clay dam placed north of the sump.

A similar dam was built south of the sump, and the water from south of Shaft No. 2 flumed across the opening under the shaft.

When the pump was put in service, delivering about 350 gallons per minute, the sump and invert of the conduit were laid dry, and operations to close the sump permanently commenced.

In the center of the sump, on a coarse gravel foundation as at Shaft No. 1, a short length of twelve-inch steam pipe with a flange top and bottom was set, with the upper flange about five inches below the line of tunnel invert. In this nipple was set the suction pipe of the centrifugal pump, which was operated constantly day and night to keep the opening dry.

Railroad bars cut about four feet long were placed at right angles and diagonally across the opening above the lower flange of the twelve-inch nipple, and securely anchored at the ends under the old concrete cradle of the conduit. Concrete was then rammed in the dry hole up to the level of the upper flange, around the nipple, and up to the line of the invert around the hole outside the nipple. The nipple, after the concrete had set for over a week, was closed with a blank flange bolted down on a white--pine gasket, and the depression of four or five inches over the cap finished to the line of the invert with a fine cement mortar.

This sump when closed was perfectly watertight.

When the sumps were closed a portion of the water which previously issued from them, forced its way through the concrete and brickwork between Shafts Nos. 1 and 3. The work at Shaft No. 2 was also conducted under the supervision of Mr. Powell.

In anchoring in place with concrete, the sump casting at Shaft No. 1, and the nipple at Shaft No. 2, due consideration was given to the pressure which would come upon them when closed, and the water forced to seek other, though less convenient, points of efflux.

The hydrostatic pressure of the water in the rock at the bottom of the conduit was roughly forty-three pounds per square inch, and the upward pressure on the sump casting at Shaft No. 1, and on the nipple and railroad bars at Shaft No. 2, was estimated at over forty tons in each instance.

The necessity of operating a power pump at Shaft No. 2 so far from the only open shaft at the north end of the conduit, imposed an unusual difficulty, and nothing in all probability could have satisfied the conditions so well as the electric current and motor employed.

Many open weepers and joints in the brickwork were found, and all these were carefully closed with poplar plugs and white pine wedges, and where considerable water flowed in spots from the roof or arch, holes were jumpered through the brickwork and concrete, iron pipe driven in, and grout pumped over the arch under pressures up to 100 pounds per square inch.

Grout was used generally in the proportion of four parts of cement to one part of fine sand, although in some cases the sand was omitted.

Upon entering the conduit, considerable dirt, debris, timber, and loose brick from the construction work was found lying

PALTE XVII.—Foot of Shaft No. 1.

PLATE XVIII.—Lining of Tunnel under Shaft No. 2.

on the invert. Planks left in the tunnel had become waterlogged and impregnated with iron from the rock water, and lay on the invert. All this material was removed, slush from the cement mortar used in laying the brickwork carefully washed out, and removed either at Shaft No. 1 or Shaft No. 11, whichever happened to be nearest.

In closing the shafts after the pumps, pipes and other hamper were removed, steel buckle plates one-quarter inch thick, bent to the intrados of the brick arches, were set on the lower flanges of the "I" beams spanning the shafts, and left in place after the brick arches were turned and covered with concrete. This was done to avoid the use of wooden centers, which could not conveniently be removed after the arches were turned.

It is probable that all the real work performed in closing the sumps and weepers, and in plugging open joints in the brickwork, and in grouting over the arches, could have been performed by the contractor before he drew the pumps from Shaft No. 1, at a cost of $1,000.00, while the operations performed under unusual difficulties, of installing new pumping machinery, hoisting apparatus, steam and water pipes, electric currents, etc., including all labor of cleaning out the conduit, cost over $22,000.00, illustrating the old adage that "Haste makes waste," and the other old adage, "that what is not in a man's head is in his heels."

Measuring the Leakage.

Information on the leakage of structures like the Torresdale Conduit is very meagre; few such conduits have been built, and very little data recorded of the water lost or gained either during or after construction, and of the structure in service. The inverted siphon of the Second Croton Aqueduct under the Harlem River; the Washington Aqueduct, and the Jersey City Conduit, are examples in point; ordinary railway tunnels are not comparable to the Torresdale Conduit, because the former are nearly always cut through elevated ridges or knobs much above tide level, are usually self-draining, and not subject to the influences of the water level in nearby streams at higher elevation than the line of the work. Exceptions may be noted in railway tunnels which pass under rivers like the St. Clair

Tunnel at Detroit, the tunnels under the Chicago River at Chicago, and under the Thames in London. The Wachuset Aqueduct, which is a similar structure, I am advised by Mr. Frederick P. Stearns, Chief Engineer of the Metropolitan Water Board, Boston, was not tested for watertightness. No evidence of leakage is known to exist, but no data have been recorded to prove absolute watertightness of the structure. No data are to be found in the office of the City Engineer of Chicago, showing either construction or service leakage of the Lake Tunnels. It is probable that these are practically watertight, because they are driven through a tough impervious clay. In the construction of the Cleveland Tunnel compressed air was used, and, aside from this, the material through which the tunnel is driven was a tough clay, practically impervious, and therefore not comparable with the tunnel driven through such material as was found in the line of the Torresdale Conduit.

GAUGING IN EMPTY CONDUIT.

The gauging in the empty conduit was done with a fifteen inch brass weir screwed to the face of a two-inch plank, about seven feet long, cut to the radius of the invert five feet three and one-half inches. The weir plate was accurately constructed with a sharp edge uniformly fifteen inches long, with a depth of notch of six inches. After this had been carefully set plumb at right angles to the axis of the conduit, with the crest of the weir level, and secured in position by bracing against the arch, and by the use of sand bags placed on the down stream side of the weir clear of the notch and overfall, the joint between the segment of the plank and the brickwork was made tight with clay, so that all water was required to pass through the notch of the weir. The gauging was done by measuring from a stiff arm attached to the top of the weir board and extended about two feet up-stream, carrying at its end a thin, vertical strip of wood with small wooden lug at the bottom. The lug was in each case carefully adjusted to the level of the crest of the weir by a straight edge and spirit level, and fixed firmly in position. The depths on the weir were gauged by means of a thin steel rule set on the lug. The accuracy of adjustment of the lug was tested before and after readings were taken, and the depth on the weir was determined

Plate XIX.—Lining of Tunnel under Shaft No. 3

Plate XX.—Closing Weeper in Invert, Shaft No. 3.

by taking the submerged length of the rule from the lug to the level of the water.

Readings of the flow in the tunnel were taken at intervals of fifteen minutes, and until they showed no further increase in the head on the weir. After the regime of water flow was established in this manner, the weir was then moved to a new station. The heads noted on the weir at different points were converted into volumes of flow after the formula—

$$q = c\,\tfrac{2}{3}\sqrt{2g}\,b\,H^{\frac{3}{2}}$$

In the following table are given the final gaugings taken before the pumps were removed from Shaft No. 1. The notes from stations south of Shaft No. 2 were taken before all the operations for reductions of the leakage had been completed, but the gaugings at Shaft No. 2, and at the top of Shaft No. 1, took into account all the water flowing at the respective stations, which included for Shaft No. 2, all leakage between that station and Shaft No. 11, and the gauging at Shaft No. 1, of course, included all water coming from the conduit. It is thus probable that the leakage south of Shaft No. 2 was less than the table shows, and the leakage from Shaft No. 1 to Shaft No. 2, correspondingly more than 364 gallons per minute.

Station	Length of Tunnel Embraced in Gauging Lin. Ft.	Flow for Station Gals.	Accumulated Flow at Station. Gals.
At Shaft No. 11	0	9	9
Between Shafts 9-10	1557.81	84	93
" " 8- 9	1345.00	23	116
" " 7- 8	1607.50	81	197
" " 6- 7	1537.50	57	254
" " 5- 6	1557.00	92	346
" " 4- 5	1508.00	84	430
" " 3- 4	1442.00	44	474
" " 2- 3	1238.00	162	636
From midway between Shafts 2-3 to, and including, Shaft No. 1	2016.00	202	838

Of the 838 gallons per minute for the whole conduit, 364, or over 40 per cent., occurs between Shaft No. 1 and midway between Shafts Nos. 2 and 3, a distance of 2016 linear feet.

For a period of fifteen days—June 1 to 15, inclusive, 1903, —at a time when the water from Shaft No. 1 and its connected headings was being pumped separately, i. e., when the water from one section of the work was not allowed to flow to and be pumped from another section, the average leakage was, at

	Galls. per min.
Shaft No. 1	350
" 2	336
" 3	122
Total	808

For a period of fifteen days—June 16-30 inclusive:

Shaft No. 1	294
" 2	416
" 3	102
Total	812

For a period of fifteen days—July 1-15 inc.—

Shaft No. 1	248.2
" 2	362.8
" 3	96.0
Total	707.0

For a period of sixteen days—July 16-31 inc.—

Shaft No. 1	305
" 2	328
" 3	95
Total	728

For a period of fifteen days—August 1-15 inc.—

Shaft No. 1	319
" 2	340
" 3	94
Total	753

For a period of fifteen days—August 17-31 inc.—

Shaft No. 1	244
" 2	346
" 3	96
Total	686

For a period of fifteen days—September 1-15 inc.—

Shaft No. 1	277
" 2	324
" 3	98
Total	699

For a period of fifteen days—September 16-30 inc.—

Shaft No. 1	228
" 2	327
" 3	89
Total	644

These gaugings were not taken with the precision of those

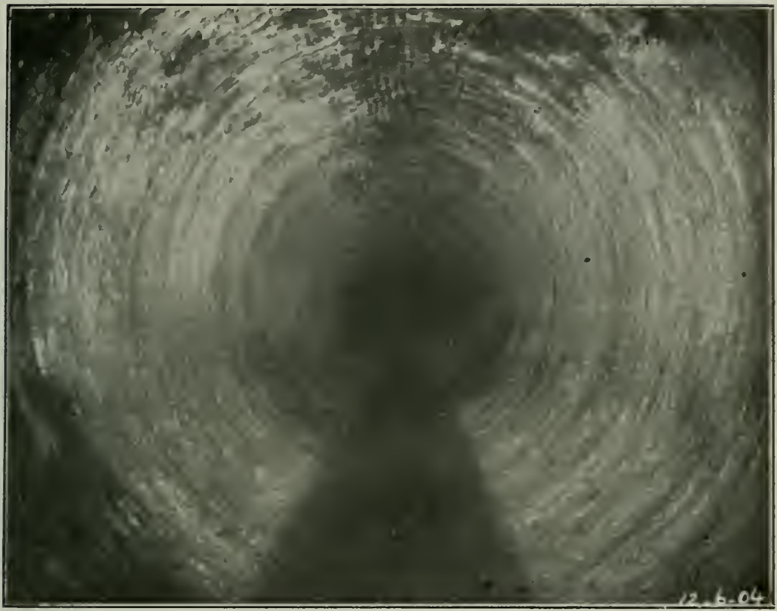
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Plate XXI.—Lining of Tunnel under Shaft No. 4.

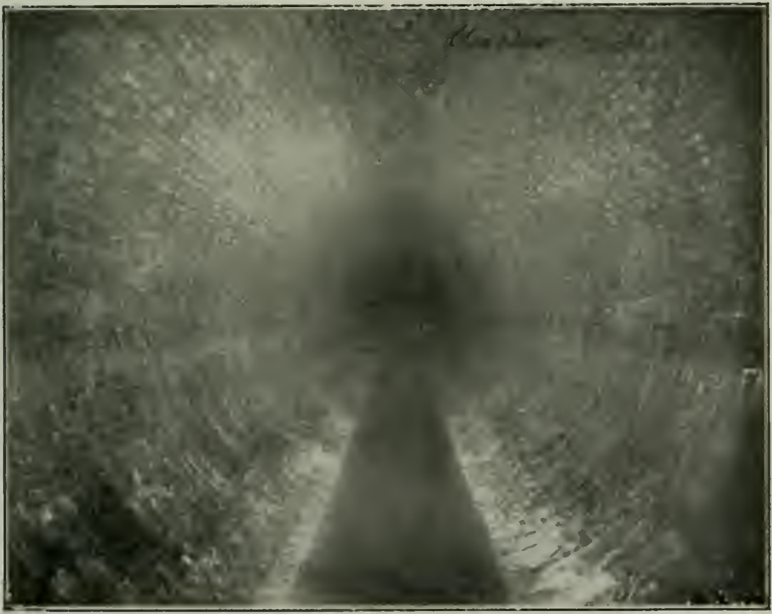


Plate XXII.—Lining of Tunnel under Shaft No. 5.

upon which the present leakage of the conduit is based, but are deemed sufficiently accurate for the present purpose, and comparing these leakages with the leakage for the same sections after the operations connected with the examination and repair of the conduit were completed, viz., 408 gallons per minute, will show a reduction of 44 per cent. A part of this reduction, of course, must be credited to the arching of the tunnel and relieving arches under the working shafts, which, however, would apply only to Shafts Nos. 2 and 3.

Upon closing the working shafts prior to April 8, 1904, readings were promptly taken of the elevation of water in the conduit at Shaft No. 1, and later at Shaft No. 11, when it rose to sufficient height to be gauged from the iron staging in the latter shaft with results as follows:

On April 8th (the first day of gauging) the elevation of water in Shaft No. 1 was 95.467 T. D., or 6.397 feet above the invert of the arch.

By April 18th, during a period of ten days, the water had risen to an elevation 182.15 T. D., at which time it was thought that the rate of inflow was too great to be accounted for upon the supposition that the sump at Shaft No. 1 and all weepers had been closed.

Prior to closing the last three working shafts, viz., Nos. 2, 7 and 9, the flow of water from the sump at Shaft No. 1 was very large, and it was though that, excepting with great care upon the part of the workmen, this sump would either not be effectually or neatly closed, and investigations were therefore begun to determine whether the last efforts necessary to reduce the leakage to a minimum had been properly made.

The best gaugings previous to closing the last three working shafts (April, 1904,) indicated a probable flow of 922 gallons per minute, divided as follows:

Station	Distance between Stations Linear Ft.	Leakage Each Station Gals.	Accumulated Leakage Gals.
From Shaft 9 to 11	2121.81	42.2	42.2
" S8 to 9	790.00	17.8	60.0
" S7 to N9	1607.50	20.0	80.0
" S6 to N8	1593.60	40.0	120.0
" S5 to N7	1452.50	92.0	212.0
" S3 to N6	2939.29	74.0	286.0
" 2 to N4	1952.10	391.0	677.0
From midway between 1-2 to 2	675.68	43.0	720.0
From No. 1 to midway between 1-2	675.69	202.0	922.0

Gaugings between all the shafts, previous to placing the larger portion of the brick lining and concrete backing, determined by the operation of the pumps at each of the respective shafts, gave leakages as follows:

Shaft	Gallons Per Minute
1	517.50
2	312.00
3	367.00
4	85.00
5	125.00
6	120.00
7	145.00
8	175.00
9	110.00
10	155.00
11	64.00
	2175.50

Comparing the last gaugings (December, 1904,) with these leakages, which generally represent the unrestrained flow of water through the shattered rock after blasting at the headings and benches, the reduction of the inflow of water amounts to about 61.50 per cent.

Considering Shafts Nos. 1, 2 and 3, the gaugings made during the first three months of 1903, in advance of the lining of the tunnel, show an average leakage of 1196.50 gallons per minute, and compared to the last gaugings taken after the lining was about completed, but before the working shafts were closed, (October, 1903), show a reduction of 46 per cent., and compared with the December, 1904, gauging, a reduction of 70 per cent.

ELEVATION OF GROUND WATER.

While the elevation of ground water has been assumed at 198.00 T. D., or slightly above high tide in the Delaware River along the line of the conduit, the gaugings taken last April after the conduit was closed, and since December 17th, when the repairs on the work were completed and the pumps and machinery removed, indicate that this may be too high, and that the mean level of ground water along the line of the conduit is not coincident with or above high tide. Of course considerable time will be required for the water to atttain its normal level, but assuming that it may be 197.00 T. D., then the difference between the maximum elevation of water in

PLATE XXIII.—Lining of Tunnel under Shaft No. 6.

PLATE XXIV.—Lining of Tunnel under Shaft No. 7.

Shaft No. 1 and ground water will be ten feet, i. e., the head on the inside of the conduit will be ten feet greater than the water in the drift and rock on the outside of the conduit.

At elevation 190.00 T. D., or seven feet below probable normal elevation of ground water, the known leakage into the conduit since the sumps and open weepers have been closed, and particularly bad spots in the roof grouted under pressure, was at the rate of sixty-five gallons per minute; and, reasoning by analogy that when the water in the conduit is at mean elevation, Shafts No. 1 to No. 11, of 202.70 T. D., or 5.7 feet above assumed elevation of ground water, the leakage would be no greater, it would then appear that the daily leakage will not be in excess of 93,600 gallons, or, say, 100,000 gallons per day, an amount which would readily be allowed for an equivalent system of cast-iron pipes operating under the same conditions.

WATERTIGHTNESS.

In preparing the plans and specification the term "watertightness" was frequently used. This was meant watertightness within the limitations of the materials to be used in lining the permanent shafts and tunnel, and no arbitrary leakage was fixed in the specification, because it was not possible, in advance of driving the headings to make an accurate calculation of the amount of water that would be encountered. It was known from the diamond drill borings along the line of the work that water would be found in the drift and rock at certain depths, and an effort was made to show at what depths water would be found, and to indicate whether the flow was large or otherwise. The diamond drill borings that preceded the preparation of the plans for the work were conducted not so much, however, to determine the presence of water in the rock as to indicate the character of the rock, and to furnish data upon which to fix the center line of the tunnel.

Considering the elevation of the center line of the conduit with reference to sea level or mean tide in the Delaware River, it should be obvious that the rock was bound to contain a considerable volume of water, and that when headings were driven into it, a flow would be encountered, the quantity of which, however, could not be determined in advance. In close grained rock, without fissures, and with little injury to seams in blasting, the flow would naturally be much less than if the rock was porous, heavily fissured, and considerably disturbed in carrying on the operations of tunneling. Therefore, it was impossible at the time the specification was prepared, to indicate any standard for leakage, but the intention was to reduce this to the least possible quantity in a brick-lined tunnel and shafts, thoroughly backed with first-class concrete.

Considering that the mean center line of the tunnel is over 100 feet below ground level, and about 100 feet below mean tide in the Delaware River, it would scarcely be reasonable to assume absolute watertightness for a work so constructed, nor is there any evidence before me, and I have sought it in records of similar works in this country and abroad, that masonry conduits of this description have ever been even approximately watertight, excepting as in the case of the Cleveland and Chicago Lake tunnels, where they are driven through a tough, impervious blue clay, and, as I am informed, no serious trouble was experienced from ground water during construction.

Under conditions of service, assuming the elevation of the water in Shaft No. 1 as 207.00 T. D., and the elevation of the water in Shaft No. 11 as 198.00 T. D., then the mean elevation of the hydraulic grade line of the conduit will be 202.50 T. D. Taking normal ground water level at 197.00 T. D., the mean unbalanced head throughout the length of the conduit would be five and one-half feet. Proportioning the leakages on the square roots of the heads with the conduit in service, and with the conduit empty:

$838 \times \sqrt{\frac{5\cdot5}{103}} = 193.60$ or say 200 gallons per minute, or 288,000 gallons per day, or less than $\frac{1}{10}$ per cent. of the carrying capacity of the conduit.

It has already been shown that the rate of leakage does not vary as the sq. root of the heads, but as some different function of the head, the value of which, for lack of time, has not been determined. In the absence of an expression which will fit the conditions of rise of water level and leakage into the conduit, such comparisons as will be made with other conduits under

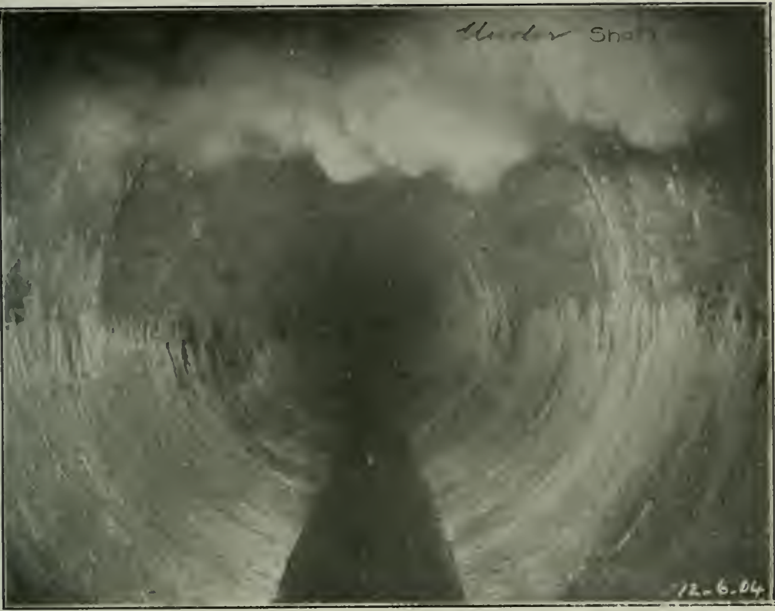
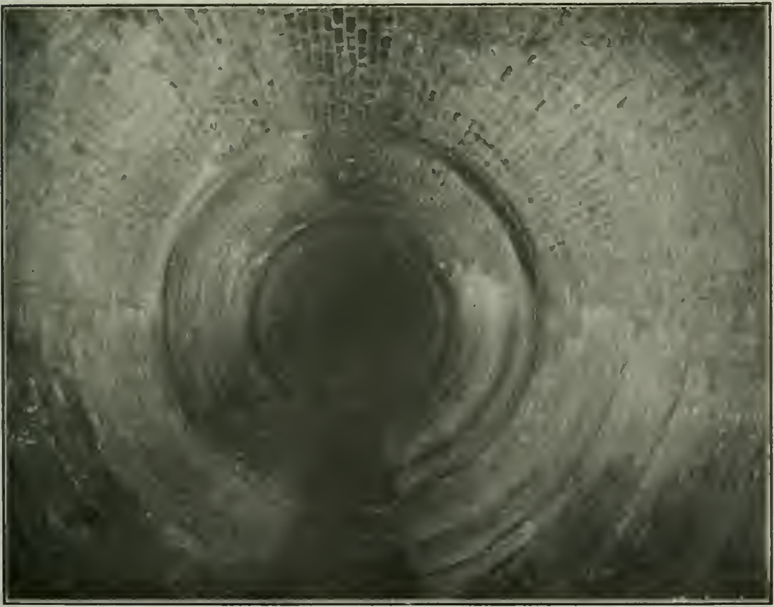


Plate XXV.—Lining of Tunnel under Shaft No. 8.



Palte XXVI.—Lining of Tunnel under Shaft No. 9.

pressure will be upon the assumption that the leakage does vary as the square roots of unbalanced heads.

Considering structures which bear a similarity to the Torresdale Conduit:

The Jersey City Conduit is a structure eight feet six inches internal diameter, lined with concrete. Section 1 has a length of 4,600 feet, of which 1,600 feet is in tunnel through shale and sand stone, and 3,000 feet in open cut. The leakage of this during construction amounted to 134,000 gallons per day of twenty-four hours.

Assuming that it was fairly distributed through the entire length of the work, this would give for the length and diameter of the Torresdale Conduit:

$$\frac{134{,}000 \times 10.58 \times 14{,}000}{8.5 \times 4{,}600} = 507{,}623 \text{ gallons per day or}$$

352.5 gallons per minute.

Section 4, of the same work, the Watchung Mountain tunnel, 7,300 feet long, is constructued entirely in tunnel, probably through the same material as was found in the tunnel operations on Section 1. The leakage of this section was at the rate of about 2,000,000 gallons per day of twenty-four hours, and the corresponding leakage for the Torresdale Conduit would be:

$$\frac{2{,}000{,}000 \times 10.58 \times 14{,}000}{8.5 \times 7{,}300} = 4{,}774{,}214 \text{ gallons per day,}$$

of twenty-four hours, or 3315.4 gallons per minute.

The head of the ground water in Section 4 of the Jersey City Conduit is probably 160 feet, and, correcting the leakage on the square roots of the heads, the corresponding leakage for a tunnel of the length and diameter of the Torresdale Conduit, and under the same water head, would be:

$$4{,}774{,}814 \times \frac{1\ \ 103}{1\ \ 160} = 3{,}828{,}919 \text{ gallons per day, or } 2{,}659$$

gallons per minute.

The New York Shaft of the Harlem River Conduit has a present leakage of about 300 gallons per minute. This is leakage from the aqueduct shaft to a pump shaft designed for use as a sump, and cannot very well be compared to the Torresdale

Conduit, because in one case it is a structure under a head, when empty, of over 103 feet, while the other is a shaft having a head varying from 0 to the depth of the shaft. If any attempt was made to compare the depth and diameter of the New York shaft with the length and diameter of the conduit, it would then appear that the allowable conduit leakage would be enormous, as shown hereafter, and it would be better to consider the leakage of the New York shaft in service with the probable leakage of the Torresdale Conduit when in service, because the leakage reported for the shaft at the New York end of the Harlem River Siphon is service leakage, and not leakage of the empty structure.

Comparing the New York shaft of the Harlem River Siphon (which is twelve feet three inches in diameter, 318 feet deep,) for water depth and diameter with the length and diameter of the Torresdale Conduit, and assuming losses of water or leakage proportioned to the square roots of the respective water heads, we have the following as the corresponding leakage of the conduit:

Wetted surface of Harlem Shaft:

$$38.48 \times 318 = 12,236.64 \text{ square feet.}$$

Wetted surface of Conduit:

$$33.25 \times 14,000 = 465,500 \text{ square feet.}$$

Ratio of wetted surfaces:

$$\frac{466,500}{12,236.64} = 38.12$$

Ratio of mean square roots of effective water heads:

$$\frac{\sqrt{103.48}}{\sqrt{141.37}} = \frac{10.17}{11.89} = 0.855$$

and the corresponding leakage of conduit based on Harlem River Shaft would be:

$300 \times 38.12 \times 0.855 = 9,777.78$ gallons per minute, or 14,080,000 gallons per day of twenty-four hours.

The Buffalo Conduit, or intake, which conveys the water from a pier at the head of the Niagara River into the pump well of the Buffalo Pumping Station, is a structure blasted through the Niagara limestone, cut to a section about 8x8 feet, and unlined. The intake is 1,020 feet long, and during construction leaked at the rate of 1,000,000 gallons per hour.

or 24,000,000 gallons per day, equivalent to 16,667 gallons per minute. The tunnel is about sixty-five feet below the surface of the ground, and probably about sixty feet below the level of water in the Niagara River.

Omitting the large flow of water mentioned above, which came from another source than the river, the leakage was said to be very small—not over 500 gallons per minute when the tunnel was empty or pumped out. Of course, when the tunnel was filled there was probably no leakage at all, because the pressure of water inside and outside would be quite the same.

Neglecting the difference of sections and effective heads of water, and proportioning leakage on lengths only, and assuming the least recorded leakage, the Buffalo Conduit for a length equal to the Torresdale Conduit, both considered as empty structures, should have leaked at the rate of 6,863 gallons per minute, or at about eight times the rate of known leakage for the empty Torresdale Conduit.

During the year 1903, *Atlantic City, New Jersey,* laid a wood-stave pipe, forty-two inches diameter, 9,807.4 feet long. This was tested for watertightness when completed under ten pounds pressure, and gave a leakage at the rate of seventy-eight gallons per minute.

Comparing this to the Torresdale Conduit, and assuming the leakage to bear some relation to the internal surface of the pipe and conduit, and that it should be proportioned on the square roots of the respective heads, then the leakage for the Torresdale Conduit compared to the Atlantic City wood-stave pipe would be 164.25 gallons per minute.

A wood-stave pipe should be as tight as a steel riveted pipe, and should represent the minimum leakage for water-carrying conduits, and yet it is evident that this leakage under the conditions of test (which I understand are substantially the conditions of service) is greater than the service leakage anticipated for the bricklined Torresdale Conduit.

An equivalent in carrying capacity of the Torresdale Conduit, as stated heretofore, would be 38.8 miles of 48-inch cast-iron pipe. An allowable leakage of 10,000 gallons per mile per day of 48-inch pipe under a pressure of fifty pounds per square inch has been a standard to which the Bureau of Filtration has endeavored to lay the various water pipes about filters

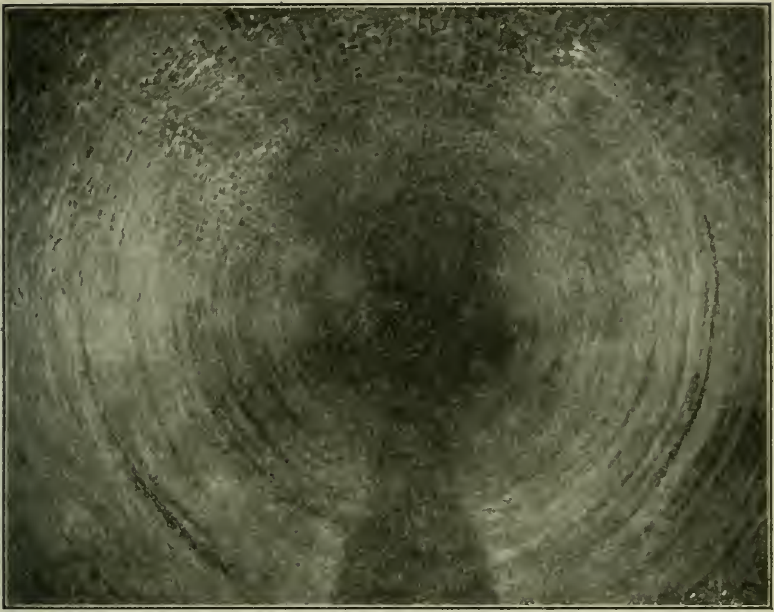


PLATE XXVII.—Lining of Tunnel under Shaft No. 10.

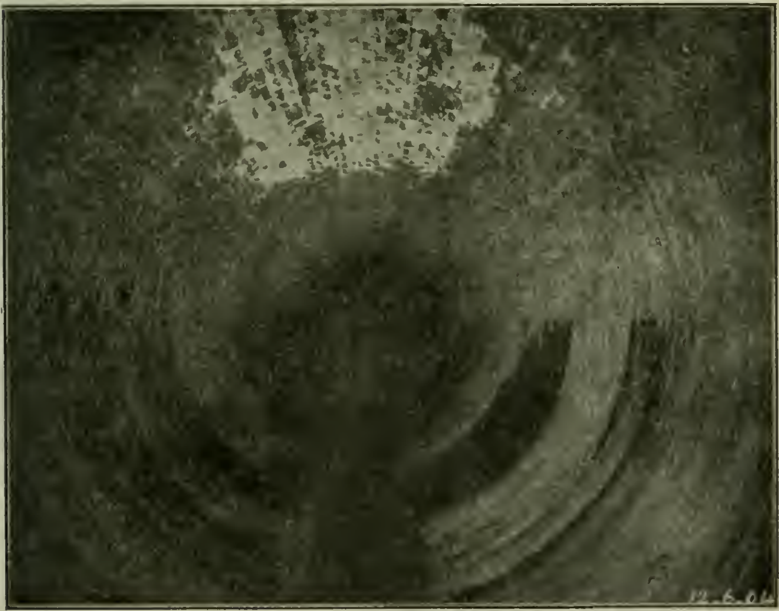


PLATE XXVIII.—Lining of Tunnel under Shaft No. 11.

and reservoirs and in the distribution systems, and assuming this value to apply to the lines of cast-iron water pipe which would have been required to balance in carrying capacity the Torresdale Conduit, the daily leakage then would be 388,000 gallons per day. The pressure on the empty conduit amounts to about 44.61 pounds per square inch, and, proportioning this upon the square roots of the pressures, an allowable daily leakage for the conduit empty compared to cast-iron lead-jointed pipes, made up in twelve foot lengths, would be:

$$\frac{388,000 \times 6.679}{7.071} = 366,448 \text{ gallons per day.}$$

The leakage of cast-iron pipe is presumed to occur only at the joints, which are spaced about twelve feet apart. In the case of the conduit, however, every brick in the lining is surrounded by a mortar joint, and if the leakage of cast-iron pipe is reduced to the leakage per linear foot of joint, and then compared with the leakage per linear foot of mortar joints in the intrados of the invert and arch of the conduit, we will have the following result:

Linear feet of lead joint per mile of cast-iron pipe:

$$\frac{48 + 2.5 \times 3.1416 \times 5280}{12 \times 12} = 5817.2 \text{ feet.}$$

Allowing 10,000 gallons leakage per day per mile:

$$\frac{10,000}{5817.2} = 1.719 \text{ gallons per linear foot of lead joint.}$$

The mortar joint per linear foot of conduit is 49.873 feet for the circular joints and 159.60 feet for the axial joints, or a total of 209.47 linear feet.

Taking the leakage of the conduit empty as 838 gallons per minute, or 1,207,000 gallons per day of twenty-four hours, and proportioning the leakage on the square roots of the pressures, fifty pounds for the cast iron pipe, and forty-three pounds (in round numbers) for the empty conduit, then the leakage per linear foot of joint in the conduit will be:

$$\frac{1,207,000}{209.47 \times 14,000} \times \frac{\sqrt{50}}{\sqrt{43}} = 0.44 \text{ gallons,}$$

and the ratio of leakage per linear foot of joint:

$$\frac{1.719}{.44} = \text{about } 4.$$

Considering the two classes of structures—one with joints everywhere throughout its length and circumference, and the other with joints occurring only at intervals of twelve feet—this is an interesting, if not the correct, method of comparison.

The gaugings for the return of ground water to the conduit since December 16, indicate that at elevation 190.00, which is seven or eight feet below normal ground water level, the leakage was practically nil, or from the records less than forty gallons per minute, showing that the theory of flow upon the square roots of the unbalanced heads will not apply.

Moreover, if it be assumed that the leakage upward for an unbalanced head of seven or eight feet would be no greater than the inward leakage for the same difference of heads between the water in the conduit and the water in the rock, the leakage then under conditions of service should be even less than the amount above mentioned. Of course, exactness in this cannot be stated at the present time, nor until the conduit is in service and exact gaugings made, based upon the displacement of the pumps at Lardner's Point.

The probabilities are that the leakage with the conduit in service will be so small that the most accurate system of gaugings for the water flowing into Shaft No. 1, and for the water flowing out of Shaft No. 11, would not indicate a difference, i. e., the relation of forty gallons a minute to 300,000,000 gallons a day, or 208,333 gallons per minute, is such that the best known methods of guaging would not show a loss of $\frac{2}{100}$ of one per cent. of the flowing capacity between the two ends of the conduit.. Even if the loss was as high as 200 gallons a minute, as figured on the basis of the square roots of heads, it would only be five times this quantity, or $\frac{1}{10}$ of one per cent. of the flowing capacity of the conduit, an amount entirely too small to be indicated with any method of gauging the flow of the conduit which could be conveniently applied.

As interesting data upon the leakage of water pipes, which bear some relation to the Torresdale Conduit, Mr. Brush reports in the "*Transactions* of the American Society of Civil Engineers" for 1888, sixteen miles of cast-iron main, varying from four to twenty inches in diameter, laid after the usual manner, as having a leakage of 750,000 gallons per day, or 47,000 gallons per day per mile.

This I should regard as a very large leakage, considering the size of the pipe.

He also reports for eleven miles of 24-inch main, a leakage of 70,000 gallons per day, or 6,364 gallons per mile, equivalent to 12,728 gallons per mile per day for 48-inch pipe. This leakage is in excess of that allowed for cast-iron pipe under the rules of the Bureau of Filtration.

Mr. Loweth in the "*Transactions* of the American Society of Civil Engineers" for 1897, reports a ten-inch pipe leaking at the rate of six hundred to eight hundred gallons per day, equivalent to 3,360 gallons per day per mile of 48-inch pipe. I do not remember that the narrator locates this pipe, nor that the figures given are the results of test. My impression is that this is what he would regard as an allowable leakage for such a pipe.

Mr. John R. Freeman, in his report to the City Controller on the Water Supply of New York, gave as data attained from Fall River, eighty-five miles of mains under from eighty to 120 pounds pressure per square inch, with a leakage of 850,000 gallons per day. This includes not only the water pipes, but also the plumbing fixtures, and is equivalent to 10,000 gallons per day per mile of pipe. Since the larger percentage of this pipe is under 24-inch diameter, it is apparent that the leakage is excessive.

In the same report Mr. Freeman mentions Woonsocket, Rhode Island, with forty-five miles of cast iron mains, under eighty pounds pressure per square inch, and a leakage of 218,400 gallons per day, including plumbing fixtures, equivalent to 4,853 gallons per day per mile of pipe. Considering that these pipes probably range from four to twenty-four inches in diameter, this leakage is excessive.

Prof. Gardner S. Williams, in the "*Transactions* of the American Society of Civil Engineers" for 1897, gives, from his experience in the Detroit Water Works, for a system of pipe four, six and ten inches in diameter, average diameter 6.06 inches, 20,607 feet long, a leakage under ninety pounds pressure of 599 cubic feet in twelve hours, equivalent to 8,961 gallons per day, or 2,300 gallons per mile. Relating this to a 48-inch main would produce a leakage of 18,210 gallons per day per mile under the stated pressure.

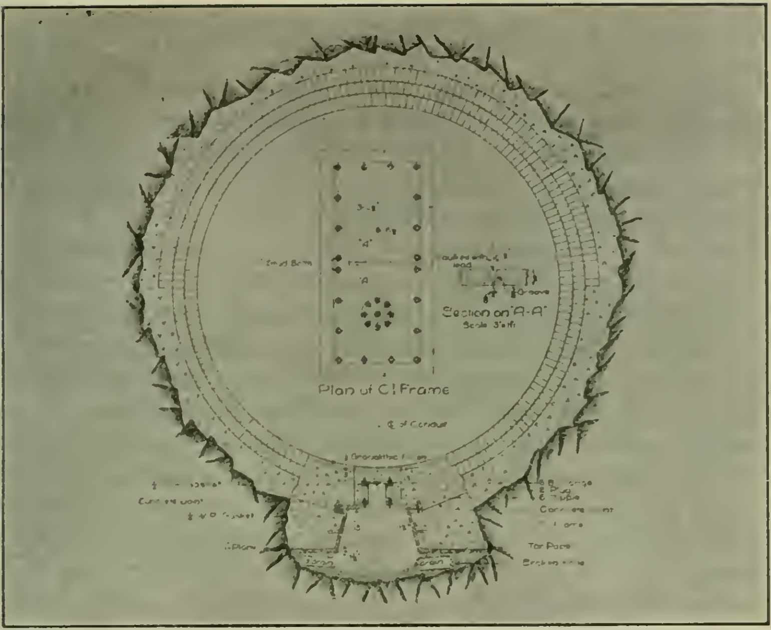


PLATE XXIX.—Method of Closing Sump. Shaft No. 1.

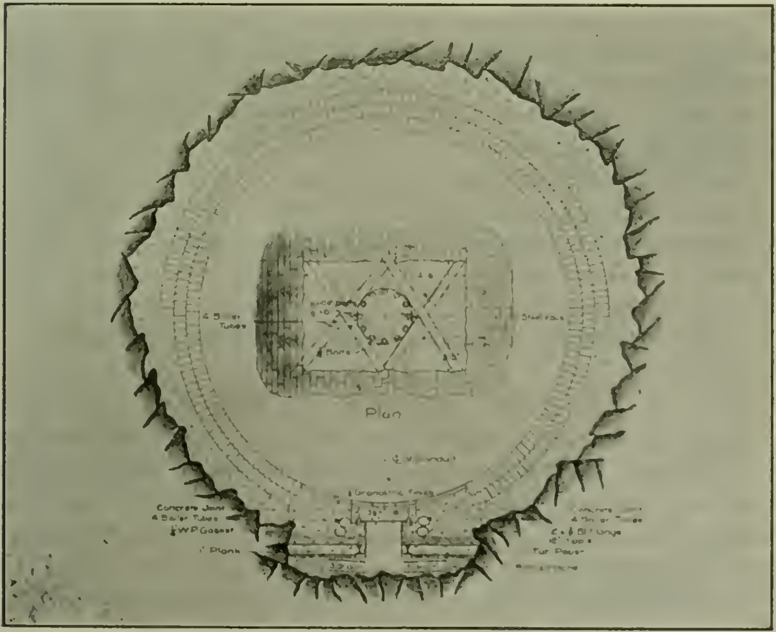


PLATE XXX.—Method of Closing Sump. Shaft No. 2.

A line of 10-inch pipe embraced in the above system of pipe, 3,487 feet long, under a pressure of forty-two to forty-three pounds per square inch, leaked at the rate of 745 gallons per day, or 1,128 gallons per day per mile, equivalent to 5,414 gallons per day per mile for 48-inch pipe.

The leakage of the Delaware River Connections, Gate Chambers and Pump Well, on Contract No. 29, Lardner's Point Pumping Station No. 2, upon test amounted to 15.6 gallons per minute. Reducing this, based upon length and with respects to the very considerable difference in pressures, the allowable leakage for the Torresdale Conduit would be 336 gallons per minute. The structures, however, at Lardner's Point, were all built in open cut, and were kept dry during the process of building, conditions much more favorable for watertight work than were those found in the construction of the conduit.

PROPOSED STEEL TUBE LINING.

It has been suggested that the conduit might have been lined with a steel tube instead of bricks laid in cement mortar. In such case probably the steel would have been made up in segments with circular and radial angle iron flanges bolted together on the inside, and the two finished internally with a ring of fine concrete or mixture of cement and sand, say $4\frac{1}{2}$ inches radial thickness.

Such construction would have increased the cost of the work by quite 100 per cent., and the annual interest charge at $3\frac{1}{2}$ per cent. on $1,274,000.00, would have been $44,590.00, or (assuming it to have been possible to make such construction absolutely watertight) about seven times the annual value of the filtered water lost by leakage of the brick-lined conduit.

REFUSE FROM CONTRACT NO. 29 FOUND IN SHAFT NO. 11.

Notwithstanding strict orders were given to the Contractor for Contract No. 29, Lardner's Point Pumping Station No. 2, that no waste materials from his operations while making connection between Shaft No. 11 and Valve Chambers Nos. 2 and 3, should be allowed to go into Shaft No. 11, upon emptying the conduit over thirteen cubic yards of waste material from this contract were found at the foot of the shaft, measuring about two feet in depth over the center of the invert, and tapering to nothing about fifty feet northward in the conduit. Unless the conduit had been emptied, no one would ever have suspected the presence of this material, which consisted of sand, cement, gravel and similar wastes. The effect of this was to reduce the sectional area of the conduit quite 11.55 square feet, or thirteen per cent. of its least sectional area.

Had this material been allowed to remain in the conduit, its carrying capacity would have been seriously reduced, and instead of charging it to the true cause, viz., that of waste material going into it through operations under another contract, it would probably have been charged to the roughness of the interior or to the insufficiency of the formulas employed for the flow of water through large conduits.

This condition, of course, was a revelation when the first inspection trip was made through the conduit after it was pumped out, and to correct it a hole was cut in Shaft No. 11, a derrick and hand winch set up and the material removed by means of a dumping bucket by hand labor, and the conduit left in a perfectly clean condition.

It is probable that if there had been no question as to the proper completion of the work by the contractor for the Torresdale Conduit (Contract No. 14), and it was known that this material lay at the bottom of Shaft No. 11, excepting it could be removed by the aid of a diver, or by some method of pumping out the material under water, it would have been profitable to have pumped out the conduit solely for the purpose of removing the refuse which came into it from Contract No. 29.

SUPPOSED DITINTEGRATION OF CEMENT.

During the past Summer, while the conduit was being pumped out for the purpose of examination and correction of any omissions or defects which the emptying of the conduit might reveal, it was suggested by a well known chemist in this city that there was some evidence of serious disintegration of the mortar in the brickwork and the concrete. After the conduit was emptied, careful examination was repeatedly made from end to end by myself and several assistants detailed for the purpose, to detect any evidence of disintegration of the mortar in the joints of the brickwork, and no evidence of injury or impairment from any cause was discovered. While considerable lime was removed with the water from the conduit during the process of pumping out, this, after the first few weeks' pumping, steadily diminished until the water attained about the alkalinity or lime content found by analysis of the water from the shafts and headings previous to the placing of the brick lining and concrete backing. The total amount of lime removed with the water amounted to about 50,000 pounds; and this should be balanced against the lime in 35,000 barrels of Portland cement used in the construction of the work. The cement, under the terms of the contract, weighed about 380 pounds to the barrel, or which, say, 62 per cent. by weight was lime, or 8,246,000 pounds; and of the lime from all known sources, not, of course, including the lime found by test in the rock water previous to lining the conduit, about 0.60 per cent. may have come from the mortar in the joints of the brickwork, and in the concrete.

I am informed by manufacturers of cement that there is a probable one per cent. to one and one-half per cent. excess of lime in the mixture, i. e., the amount of lime is usually slightly more than is really required to make a perfect cement. The influence of this upon either the strength or hardening properties of cement is not noticeable, and if it be assumed that there is a slight excess of lime, it would be possible to lose even a larger percentage than was shown by the estimate of lime lost in pumping out the conduit without impairing the quality of either the concrete or the mortar in the brickwork.

Under the conditions of service it is not thought that the slight outward leakage of filtered Delaware River water will have any serious effect on the lime in the cement, and this opinion is based upon long observation of the influence of water low in lime content, like that of Loch Katrine, on the cement plastering and mortar in the joints of the masonry of the first Glasgow Aqueduct.

Analysis of Water Flowing into the Shafts amd Headings.

During the construction of the work samples of water were collected monthly from the shafts and headings, and analyzed for mineral content and bacteria. The rock water, as would naturally be supposed, excepting for the considerable amount of iron it carried, was unobjectionable from a sanitary point of view. The bulk of the leakage into the conduit when empty occurred north of Shaft No. 4, or within the first 3,500 feet of tunnel length, at which point, under conditions of service, the pressure of water in the conduit will be greater than the pressure of water in the ground and rock, and the leakage will be of filtered water into the rock and not of rock water into the conduit. The leakage, therefore, does not represent any possible menace to the quality of the water supplied from the Torresdale Filters, but does represent a loss of filtered water, the value of which has been previously noted.

Under conditions of service, with the conduit delivering 300,000,000 gallons per day of twenty-four hours, the lowest elevation which it is expected the hydraulic grade line will take in Shaft No. 11, is 198.00 T. D., or about the maximum elevation heretofore noted of ground water along the line of the work. Of course, when the flow is less than 300,000,000 gallons per day, the hydraulic grade line at Shaft No. 11 will be correspondingly higher, and it would be only at such times as the flow is increased to more than 300,000,000 gallons per day, or for some other reason, the hydraulic grade line might be lowered throughout the length of the conduit, that the elevation of the water in Shaft No. 11 would be below that of the ground water, when a small amount of ground water may find its way into the conduit south of Shaft No. 10. Should this occur, no uneasiness need be felt as to its influence on the very large volume of filtered water flowing through the conduit, and indeed it is doubtful if careful technical tests would show any change in the character of the water at Lardner's Point by reason of the small admixture of water from the rock surrounding the conduit.

In closing this paper I take pleasure in acknowledging the faithful and indefatigable labor of Mr. T. Nelson Spencer, First Assistant Engineer in charge both of the original construction and the examination and repair of the conduit; also, to the work of Mr. Louis R. Snow, Official Photographer of the Department of Public Works, who took the flash-light photographs in the tunnel and the other pictures, and prepared the slides which have been so useful in illustrating construction features of the Torresdale Conduit.

THE PRACTICAL SIDE OF WIRELESS TELEGRAPHY.

A very pretty example of the everyday usefulness of wireless telegraphy turned up the other day when an incoming Cunarder was reported in Boston from a point nearly 800 miles from that port. She was picked up by the Cape Race wireless station and the ordinary wires did the rest. Notice of the probable hour of her arrival in spite of delays which she had experienced was thus given almost two days in advance, to the great convenience of everybody concerned. The same thing will be regularly repeated in all probability, and thus the gap of isolation on the transatlantic voyage will be greatly narrowed. Quite aside from long distance feats, the art of wireless telegraphy can thus be made immensely more useful to mankind than it has yet been. It is not at all necessary to send wireless messages across the Atlantic, for we have the cables already, although active competition with the wireless system would doubtless be some advantage. With the system as we have it to-day, splendid work has been done over distances great enough to be immensely useful, and even if unforseen difficulties block regular transmission half way across the world, we may well be thankful for what we already have. In the Russian-Japanese war the system has shown its immense value in naval operations. The conceptions of a blockading fleet being held at a safe and convenient base until being warned by its scouts that its presence is needed is distinctly worthy of this twentieth century of ours. But the uses of the system in peace will prove still more important, even with greater limitations in distance than are likely to prove permanent. The ocean is no longer an unbroken waste of waters, and by taking advantage of capes and islands the greater part of it can be covered by a wireless system without requiring transmission over more than a few hundred miles in any single stretch.—*Elec. World.*

TREE PLANTING ON THE PENNSYLVANIA RAILROAD.

At the recent convention of the American Forestry Association, in Washington, D. C., Mr. Joseph T. Richards, Chief Engineer of Maintenance of Way of the Pennsylvania Railroad, gave an address on timber cultivation to supply railroads with ties, and the following statements are taken from press reports of that address: Seedlings, two to three years old, cost by the time they are planted, including labor, 8 cents each. They were planted ten feet apart, averaging about 400 to the acre, although 54,871 trees recently were planted 6 feet apart, and 88,127 were set 8 feet apart. The total number planted by the railroad company is as follows: Newton Hamilton, 13,610; Conewago, 68,460; Pomeroy, 20,280; west of Atglen, 16,537; Atglen, 8,108; Juniata Bridge, 20,730; Newport, 29,505; Vintage, 50,3000, and along the Atglen and Susquehanna Branch, 53,000, a total of 280,530 trees. The land, except a tract of 14 acres at Newton Hamilton, is owned by the railroad company. To supply the increasing needs of Pennsylvania alone Mr. Richards estimates that it will be necessary to plant 1,300,000 trees each year for a period of thirty years, the time required for a tree to mature.

ELECTRICAL SECTION

Stated Meeting, held Thursday, February 9, 1905.

The Inspection of Electrical Conductors, With Especial Reference to Fire Protection.

By Washington Devereux,

Electrical Engineer to the Philadelphia Fire Underwriters' Association.

The author, who occupies the responsible position of Electrical Engineer to the Fire Underwriters' Association of Philadelphia, gives, in this paper, a concise statement of the progress and present condition of the science of interior wiring for the protection of buildings from fire from the many sources of danger due to imperfect methods of electric installation.—[The Editor].

Possibly there is no better way to treat the subject before us this evening than to commence at the beginning and with the steps taken to raise the standard of electrical equipments and the introduction in buildings of the same.

At an early stage it was found necessary to regulate the manufacture and introduction of electrical equipments. To the English insurance interests may be attributed the credit of compiling the first code, better known as the "Phœnix Fire Office Rules." The rules were somewhat prohibitive, due to cost of installation of apparatus required. In the early days electric lighting apparatus and materials were far more expensive than at present.

The use of electricity for lighting purposes was a rare novelty, and only for the favored few of great wealth. Electricity for power purposes was unknown.

The insurance interest of America were far more lenient and generous than our British cousins.

Perhaps we were not so well posted in knowledge of the hazard involved and were therefore eager to learn and gain a knowledge to ourselves of that mysterious power of electricity.

We have learned much in the past twenty-five years, and yet how little we know after all. In the light and power world "a little knowledge is dangerous indeed," if the individual thus afflicted ventures too far unassisted.

As a rule the insurance companies pay for the lack of knowledge.

In the past twenty-five years many fires have originated from defective electric equipment. Many regulations were published by the insurance and electrical interest in an effort to correct previous errors, and while the advancement has been none too rapid in reducing the fire hazard, a marked improvement in the past twenty-five years is most pronounced, and we trust the next decade will enable the engineering world to reduce the hazard of electricity to a minimum.

During the time spoken of opinions as to the best method of installations varied very much among the insurance and electrical interest, and there was strong desire on the part of both to establish a code, which would be acceptable to those most effected.

And while there is quite a difference of opinion regarding some details, on the whole the present regulations are commendable.

To-day we have the National Electrical Code, which is the result of a gradual development originating with the Phœnix Fire Office Rules, having for its primary object the reduction of the fire hazard from electricity, and secondly, a uniform requirement which could be mutually recognized by the insurance and electrical interests, and a basis for the acceptance or rejection of electrical installations.

We do not claim this an ideal code, as experience has shown the necessity for improved equipments. This code is, nevertheless, the expressed opinion of the combined insurance and electrical interests.

A word about the code and its application.

To those who are less familiar with the code the following outline will appeal:—

The General Plan governing the arrangement of the Rules is as follows:—

Under *Class A,* Rules 1 to 11, govern the location, arrangement, construction of material, acceptable in Central Stations; Dynamo, Motor and Storage Battery Rooms: Transformer Sub-stations, etc.

Under *Class B,* Rules 12 to 13, governing outside work, all systems and voltages.

Under *Class C.* Inside work. Rules 14 to 17 govern general requirements, all systems and voltages. Rules 18 to 20 apply to constant current system.

Rules 21 to 23 consists of general requirements for all voltages, constant potential systems.

Rules 24 to 34 apply to Low Constant Potential systems, 550 volts or less.

Rules 35 to 37 apply to High Constant Potential systems, 550 to 3500.

Rules 38 to 39 apply to Extra High Constant Potential systems, over 3500.

Under *Class D,* Rules 40 to 63 apply to the details of construction and materials of fittings, etc., all systems and voltages.

Under *Class E,* Rules 64 to 67 apply to miscellaneous construction, such as signalling systems, electric gas lighting and moving picture machines.

Under *Class F,* Rules 68 to 83 apply to marine work.

It is almost universal in the United States that installations or equipments should comply with the requirements contained in the National Electrical Code, the latter having been adopted by all local Boards of Fire Underwriters.

The development of the code was slow, insomuch as a piece of apparatus or a class of construction was accepted and regulated before its hazard could be determined.

Thus the application of both apparatus and construction has in some cases been confined to narrow limits as the result of experience.

The "National Electrical Code" may thus be said to be the result of broad experience classified.

As we look we are somewhat amazed at the marked difference in the construction and installation of apparatus.

During this period certain features seemed to mark a new era in this particular line, yet in but a short time another feature of equal import was introduced.

The history of the "National Electrical Code" is made up of a series of discoveries which will be dwelt upon this evening.

At an earlier date the importance of wire insulation was not recognized, and bare copper conductors, with a difference of potential from 300 to 500 volts, were stapled to woodwork, and this method of construction was considered good practice. Difficulties were encountered as must be expected, such as electrolytic action, grounds, short circuits and fires, and these were only limited, due to the fact that very few plants were in operation. It was learned that these difficulties could be reduced to some extent by covering the conductors with insulating material. This led to covering the conductors with cotton paraffined. These insulated conductors were held in place by means of wooden cleats. Such an insulation is highly inflammable, and while some difficulties were eliminated, the fire hazard was greatly increased. This led to the adoption of the "Underwriters" wire. The insulation on this wire consisted of cotton and asbestos fibre, impregnated with white lead. This insulation was fireproof (and was and is to-day most serviceable in hot drying room, boiler houses and places of like nature), but not damp proof, reducing to some extent the fire hazard, but presenting the serious objection, an insulation materially affected by dampness, having a very low, insulation resistance compared with that of cotton paraffined wire.

The wiring contractors make formal application for inspection to the underwriters having jurisdiction. The examinations are made by trained inspectors, whose duties require a strict compliance with the requirements. In the examination points not covered by the code are pointed out and corrected.

This inspection tends to educate those directly or indirectly connected with electrical matters by this transference or interchange of ideas.

New ideas are reserved for future consideration by the National Board of Fire Underwriters, and after acceptance are made a part of the revised code.

Thus the latter is a flexible requirement, changing with the changing of ideas or customs, adjusted to suit these new ideas and costums, but always improving.

In addition to the use of wood cleats for mechanical support, the conductors were laid in V-shaped grooves in wood joist, unprotected except by the wire insulation.

The conductors were subject to mechanical injury and breakage, as the floor boards were sometimes unevenly laid, very often loose, and a constant wear was sustained by the conductors, as the occupants of a building would tread upon the surface wired over. Occasionally joists were bored and the conductors drawn through wooden base switches and open-link wooden cut-outs served as controlling and safety devices in all cases on low potential system, 110 to 220 volts.

The weakness of the above methods were soon noticed and eliminated to this extent, the conductors were no longer laid in V-shaped grooves, and the holes in joists through which conductors passed, were bushed with soft rubber tubing. This insulation proved a failure. Then followed the hard rubber tube; failure again. Papier maché tube treated with several coats of asphaltum, then papier maché sheathed with brass. All in turn were failures, lacking qualities desired and necessary solder was at a premium, judging from the number of unsoldered joints. Tin foil was often used as a substitute, principally with a view of deceiving the inspector.

The necessity for support of higher insulating qualities developed the porcelain knob and cleat. The application of glass and porclain to the manufacture of insulators and of porcelain to the manufacture of cut-outs and switch bases was a marked stride in the development of higher quality of electrical fittings.

The "Underwriters,'" or composition asbestos wire, had in it the weak feature that it was readily affected by moisture. This wire was later covered with a cotton or hemp braiding coated with asphaltum, pitch and tar, or a composition simliar to Chatterdon compound, making a comparatively good insulation. While fresh this insulation will burn readily, but when thoroughly dried out is of slower combustion, and is commercially known as "Slow-Burning," sometimes "Fire and Weatherproof." The latter title, however, is erroneous and misleading.

The necessity for an insulation having a higher value than "Underwriters'" and "Slow-Burning" insulations was apparent and lead to the construction of rubber-covered wire. This was followed with a rubber-covered wire having a single outer wrapping of tape. Two weaknesses were noted. First, the copper wire was chemically affected by the sulphur mixed in with the rubber, and second, the outer covering dried up, unwrapping or otherwise exposing the inner insulation to a varying atmosphere, eventually drying and cracking the rubber. The first trouble was remedied by tining the wire, the second by applying a braid of one, two or three layers.

From the number of layers of braid we name the wire, for instance the triple braid having in addition to the rubber insulation, three distinct braids of insulating material.

Undoubtedly the braid greatly enhanced the insulating value of rubber covered wire.

We have briefly scanned the field, from the use of bare wire stapled to the rubber-coverd wires, mechanically supported by knobs and tubes.

This is indeed a great improvement and it will no doubt surprise you to note a backward step.

Knob construction was found objectionable from an artistic standpoint, also because the wiring in many instances was subject to mechanical injury. The circuits thus disarranged coming in contact with gas pipes, water and steam pipes, causing grounds, leaks in multiple, and many times creating a fire of more or less magnitude. Thus the need for some device that would entirely conceal the wire, brought forward the "Astrakan" moulding.

This moulding was made of hard wood, grooved in the back. The wires were laid in the grooves and nailed anywhere. This class of construction was not without fault and its adoption was indeed a backward step.

The rubber wire very often resting against new plastered walls and ceilings was acted upon by the chemical limes, etc., rapidly deteriorating the insulation and creating a fire.

The "Astrakan" moulding was soon replaced with the present two-piece moulding, though of lighter construction and untreated with a moisture repallant and the same disastrous results followed, as in the adoption of the "Astrakan" moulding, to a lesser degree, however.

The present moulding is of heavier construction, thoroughly treated with two and sometimes three coats of moisture proof paint and has proven fairly satisfactory. Care, however, is needful never to install moulding work in wet places or where the possible overflow of a tank, sink or accidental breaking of a water pipe may saturate the moulding and thus cause a fire.

Attention was given to the development of some form of insulation between gas fixtures and the house piping. Insulting joint having soft rubber insulation was adopted, but failed owing to the chemical changes in the rubber and its mechanical weakness.

The principal weakness, however, was the extreme inflammability of the rubber. "Bug" cut-outs were invariably placed in the canopies of fixtures. The melting of a fuse many times would flash sufficiently to ignite the soft rubber which quickly communicated with the illuminating gas contained in the house piping, creating a fire close to the ceiling. Sometimes side brackets were thus effected, located on hollow frame partitions. The fires were not easily controlled, as it was always necessary to turn the gas supply off at the meter. Before this could be accomplished a fire of no small proportion sometimes occurred.

The soft rubber joint after a few years proving unsatisfactory and unsafe, was replaced by the hard fibre joint and finally the mica insulating joint, while not indestructable, when subjected to an electric arc has proven more satisfactory than any insulating joint yet produced.

The introduction of the mica insulating joint greatly reduced one of the most serious weaknesses in an electrical installation.

If we will but consider that the combination gas and electric fixture contained two factors, having dangerous characteristics if improperly handled, one being able to puncture the gas pipe and the gas ignited by the consequent spark (arc), we more readily appreciate the real value of the insulating joint. The possibility of grounds to earth on fixtures attached to gas piping has been reduced by the use of the mica insulating joint. It was also required to cover the wires at the outlet to avoid possible contact with the house piping. This was accomplished by covering the wires with soft rubber tubing, a poor remedy. Later the improved means of flexible, slow burning tubing, and finally procelain tubes.

"It is also recommended that the gas outlet pipe be protected above the insulating joint by approved insulating tubing, having a flange at the lower end where it comes in contact with the insulating joint." The use of electric gas lighting on the same fixture with electric lighting is most inadvisable, as the insulating joint is rendered practically worthless by the gas lighting wires bridging the insulating joint. In fact, straight gas or straight electric is the best practice.

Probably no portion of the electrical equipment, with one exception, is more roughly handled than the sockets and the introduction of the lined socket was a marked improvement indeed.

The great need of a wireway or raceway for electrical conductors was most apparent. A method system, if you please, whereby the electrical conductors could be more systematically installed and at the same time practically accessible at all times. The desire to better general conditions brought forth the "Interior Conduit System," which consisted of tubes of papier mache, treated with several coats of asphaltum, an excellent insulating compositon, but very inflammable. Iron outlet and junction boxes into which the tubing and open link cut-outs nicely fitted, completed the system and was pronounced by many as ideal. The owners of these patents and stockholders reaped large financial gains.

The serious objection to this system was its freedom to mechanical injury and its inflammable qualities. The applying of an outer thin brass covering, forming what is known as "Brass Armored Tubing," did not remedy the difficulty, as the brass was readily punctured, adding an additional defect in the form of a sharp projection, very often cutting the insulation and increasing the fire hazard.

The great problem is how to secure safety, and this may be answered: By the proper method of construction, using only high grade material.

The fire hazard should be always carefully considered in an electrical installation, and the National Electrical Code carefully applied. In applying the code care must be taken in the proper discrimination of the hazard and to apply that electrical system which will be less apt to increase the hazard. The equipment should be installed by skilled wiremen, guided by experienced engineers.

Evidences of the lack of knowledge on electrical subjects are quite apparent; nails and screws driven into electric light and power moulding, wires in contact with gas pipes, water pipes, water tanks, metal awnings, metal ceilings, iron beams, cornices, awning frames and metal signs. The introduction of various auxiliary devices for varying the candle power of lamps, lamps in series with bell and telephone systems and connected to lighting systems, and other similar makeshifts, are in the wrong direction, increasing the fire hazard, not necessarily because of faulty construction, but because their constant manipulation is in the hands of those less informed or absolutely ignorant of the danger involved.

In the manufacture and distribution of electrical energy there is a loss by heating due to the fact that all substances have a resistance which has to be overcome and which represents a loss in energy, which is substantially all transformed into heat. The heat which is produced in a wire only depends on the number of watts expended electrically by the current in overcoming the resistance of the wire, which resistance varies with different materials, and goes to raising the temperature of the conductor and indirectly that of the surrounding bodies; and this rise continues until the rate at which heat is lost equals that at which it is generated; then the temperature becomes constant. It is obvious, therefore, that an electrical conductor is only capable of carrying a certain current with a given elevation of temperature, and, practically the allowable temperature is limited by consideration of injury to insulation and the danger of fire.

The lined iron conduit was next introduced. The conduit was of iron, having the general characteristics of gas pipe as tc size and quality and was bushed throughout its entire length with a treated wood else papier maché lining.

This class of tubing presents numerous objections. The most serious is perhaps its liability to fracture the insulation of conductors during the process of "drawing in," the wood lining often giving way, forming sharp projections and puncturing the conductors.

This tube was soon followed by a galvanized iron pipe, similar to gas pipe, but galvanized to prevent corrosion.

The iron conduit is an inflexible system, and the demand for a system of piping having all the properties of iron conduit with additional flexibility, led to the "Flexible Iron" conduit system.

The outline here shown of the improvements in methods of construction are only the more important.

The step from uninsulated wire stapled to double braided rubber covered wire in metal conduit is a big one, covering more than twenty-four years of slow and steady care in selection.

The insurance inspector has played no small part in these improvements. His experience with the various classes of apparatus or of construction has sifted out the bad features and only the most improved appliances and fittings withstand his criticism.

After years of experience, of tug and tussle, of acceptance and rejection, has resulted in the present National Electric Code.

The temperature elevation of a wire for a given current strength depends upon its resistance, diameter, covering, and its surroundings. A copper wire carefully insulated by a thin coating of water-proof material and placed in still water is usually kept comparatively cool, owing to the rapid conduction of heat through the insulated cover into the water.

The same wire, carrying the same current, but suspended in air instead of being immersed in water, will usually attain a considerably higher temperature, as still air does not carry away heat from the surface of the wire so effectively as still water. For the same reason a wire buried in the ground will, in almost all cases, be found to be cooler than where supported in the air. A covering of, say, cotton, rubber, or other electrical non-conductor will, up to a certain thickness, serve to cool the wire by increasing its surface.

The same heating conditions would apply to switches, switch or fuse lugs, bus-bars, commutators, and in fact to any current-carrying parts of a circuit, and it is therefore necessary that they be sufficiently heavy to carry the required current without undue heating.

Heating may be the result of insufficient contact surface, and the tendency in all cases is to increase the temperature to a dangerous point, or to melt and ignite the insulation of an inflammable nature, such as rubber and cotton. It is necessary, therefore, that the carrying capacity of current-carrying parts and of contacts shall be limited.

Poor connections at fuse blocks may produce heat enough to cause the fuse to melt when there is really no trouble elsewhere on the circuit. This may occur when the fuse blocks have too little contact surface at the connection points to properly carry the current, or when the contact surface is not secure, in which case arcing occurs, pitting the surfaces and intensifying poor contact.

The formation of an arc may be understood by the following explanation: The two conducting terminals under ordinary circumstances are brought together before being separated to establish the arc. As soon as this separation commences, the spark which tends to form at any break in a closed circuit vaporizes a portion of the materials of the electrodes, thus establishing a bridge of conducting vapor through which the current flow is maintained. The concentration of energy in a small space produces an intense heat, which vaporizes the electrodes more rapidly. The temperature of this arc, although difficult to determine accurately, is about 3500° C. We may obtain an approximate idea of this heat when we consider that about 500° C. are necessary to make solid bodies glow with light, and that the melting point of platinum is 1775° C.

As was noted previously, the presence of two leaks on an electrical circuit, creating an electrolytic action and finally a break in a circuit, is attended with the destructive arc. It is equally true that the breaking of any circuit, whether it be by means of a properly proportioned switch, the melting of a fuse, or the breaking of a current-carrying wire, is attended with this arc. Where the numerous blowings of fuses have occurred, the porcelain surface of the fuse block is often covered with a layer of metallic substance, which becomes a partial conductor. Upon the repetition of this blowing, an arc is formed and maintained by this metallic layer; in many cases the porcelain cover is fused and broken.

In other cases, particularly slate switch and distributing boards, the melting and resulting arcing have been known to crack the insulating substance and the various conductors short-circuited. In other cases the short-circuiting of an incandescent lamp has destroyed the sockets or controlling devices beyond repair. The throwing out of sparks from arc lamps and the dropping of hot carbons have been known to cause fire. Sparks from the commutator to motors, from the short-circuiting of flexible cords and of fixture wires, from the short-circuiting of cables in conduits and in manholes, igniting accumulated gases; from short-circuits in sockets, attachment plugs, receptacles, switches and various other devises have been known to cause fire.

Overheating of wires, of motors, dynamos and switchboards from overloads; overheating of starting boxes; overheating of theatre dimmers and regulating boxes from overload; overheating of improperly made joints, which may be considered the weakest part of an installation, and may include joints between wires, between wires and lugs, between lugs and busbars, or between switch blades and clips; overheating of magnet coils or resistance of arc lamps, and innumerable other similar defects have been known to create a fire.

Other sources of fire may be the contact of an incandescent lamp with inflammable material, such as cotton, paper, wood, celluloid goods, etc.; the melting of fuses, the breaking down of insulation, sparking from electrolysis, or short-circuits in places impregnated with inflammable gases, such as benzine, naphtha, ether, hydrogen, gasolene, and many others of explosive nature; also in any class of manufacture where vegetable material is distributed through the atmosphere in the form of dust, extra precautions are absolutely necessary, the least flash or arc being sufficient to cause an explosion.

Candy factories, sugar refineries, flour mills, breweries, saw mills and others of like hazardous nature may be considered in this category; also textile mills, where there is an accumulation of the particles of stock that is carded out, which particles, owing to their extreme lightness, fill the air in the rooms, and, settling, completely cover everything with an inflammable material usually known as "fly," which is a fine dust of vegetable matter. In this condition the dust may be ignited by the blowing of a fuse or similar accident.

It will be noted from the remarks made in this paper that electricity is treated as a source of heat and as such is classed as a fire hazard, and it is fair to say that it presents to us a most dangerous and powerful factor in that respect, if an equipment is improperly installed, abused, or permitted to be neglected.

That electrical equipments are abused and neglected is a fact too well established to permit of argument.

This is particulary true of isolated plants.

There is no class of industry which should receive greater consideration than the interior wiring of buildings for light and power purposes.

A word to the public:—Engage only reputable electrical contractors and engineers, who in turn may be presumed to employ artisans skilled in their calling; and, as a further precaution do not pay a bill for additions, alterations or repairs to any portion of an electrical equipment until a certificate of approval has been furnished by the Board of Fire Underwriters having jurisdiction, or other properly constituted authorities.

In referring to the fire hazard of electrictiy, we must not lose sight of the fact of the great benefits which this subtile force has bestowed upon mankind.

Electricity will cause fire under certain conditions; the same agent, regardless of the cause of fire, is used in sending out the fire alarm, affording quick and ready relief. This may be accomplished by the police and fire alarm systems, else the automatic alarm, a silent monitor and a watchman, who never sleeps. By the same power the electric fire pump automatically supplies water in abundance to the fire mains, stand pipes and automatic sprinkler systems, thus rendering great assistance to the fire department in the execution of their duty.

By the aid of electricity we can send by telephone or telegraph messages to all civilized parts of the earth.

Civilization is crude indeed if electricity has not made its impress upon the surroundings.

Humanity has greatly benefited by the use of the Finsen and the X-Ray.

Electro-therapeutics to-day is indispensible to the medical and surgical world. In fact to enumerate the innumerable great and lasting benefits which electricity has afforded humanity is a task beyond the ability of any man.

After due consideration of the fire hazard involved, we must admit, if properly installed and not abused, electricity is the safest source of light which the ingenuity of man has produced, and its fire record is far below the oil record and its casualties are nil when compared with oil lamp statistics.

"Platinoid," mainly a nickle-copper allow, owes to the presence of a little tungsten its peculiar property of having a higher electrical resistance, which does not change with temperature.

CHEAP STEAM PRODUCTION.

A letter to the editor of *Engineering* (London), printed in a recent issue of that periodical. was evoked by an earlier letter asking whether the cost of 2 shillings 4 pence (56½ cents) for evaporating 1000 gallons of water can be beaten. The writer sends particulars of a test made at James Oakes & Co.'s Riddings Colliers, near Alfreton, England, on April 19 of last year. The plant consisted of a Lancashire boiler fitted with two patent hot-air furnaces, supplied by the Hot-Air Furnace Company, Birmingham, England, and one of its downtake superheaters. The following are the data given:

Size of boiler	8 feet diameter by 30 feet long
Average boiler pressure	80 pounds
Temperature of saturated steam	324 degrees F.
Temperature of superheated steam	540 degrees F.
Degrees of superheat	216 degrees F.
Temperature of feed water entering economizer	90 degrees F.
Temperature of feed water entering boiler	250 degrees F.
Temperature of gases entering economizer	540 degrees F.
Temperature of gases entering chimney	230 degrees F.
Pounds of water evaporated per hour (actual)	9,768
Pounds of water evaporated and superheated per pound of coal (actual)	9.5
Equivalent evaporation of saturated steam from and at 212 degrees pound of water per pound of coal	12.2
Class of fuel	Dirty slack
Cost of fuel per ton at colliery	48½ cents
Actual cost of fuel to generate and to add 216 degrees F. of superheat to 1,000 pounds of steam	2¼ cents
Equivalent cost of fuel to generate 1.000 pounds of steam from and at 212 degrees	1¾ cents

This shows that the actual cost of the fuel to generate the steam from 1000 gallons of water and superheating it 216 degrees is but 11¼ pence (22½ cents), as compared with 1 shilling 11 pence (about 46 cents) for the general ing of steam in the boiler previously referred to.

TESTING OF WIRELESS TELEGRAPH SYSTEMS.

It is understood that the various systems of wireless telegraphy now in use are to be tested in the annual naval maneuvers in the Caribbean Sea. Plans are being made for elaborate tests, and a majority of the vessels participating will be equipped with the wireless apparatus. Two or three different systems will be used and every effort will be made to intercept wireless messages and to break the lines of transmission. The vessels of the squadron will, as far as possible be controlled by wireless telegraphy from the beginning of the maneuvers until the fleet comes north to Pansacola in March for target practice. Every effort will be made to test the efficiency of the instruments now used by the government.

Section of Photography and Microscopy

A Solid Invisible Bifocal Lens.

Stated Meeting, held Thursday, January 5th, 1905.

By J. L. Borsch, M. D.

In this paper is described the evolution of the bifocal spectacle lens, leading up to a substantia improvement devised by the author, in which the objections to the present composite bifocal lens are avoided by the successful construction of a solid invisible bifocal glass.—[The Editor].

When asked by your President to read a paper here I could not help remarking how appropriate a place is the Franklin Institute to present a paper entitled "A New Bifocal Lens," since it is to the distinguished statesman and inventor for whom this institution was named that we owe the invention of Bifocal Lenses.

Their history is interesting, in that it portrays quite vividly the fact that one often tries many complicated means to accomplish a thing which can be done very simply—when one knows how to do it.

It is my purpose to state briefly the conditions of the eye in which these lenses are used, to review their evolution and to say a few words regarding the new lenses.

With your kind indulgence a few facts in Physiological Optics will be recalled in order that all may better understand the use of Bifocals, or glasses with which one can see both near and far.

The principal optical defects are due, 1st, to an anomaly of curvature of the cornea or the crystalline lens, or 2nd, to an abnormal composition or condition of one of the refractive media of the eye. They both cause practically the same symptoms; but most optical defects are due to an anomaly of curvature.

The cornea is that membrane which is to the eye what the crystal is to the watch, and must be of equal curvature in all meridians and perfectly transparent, so that parallel rays of light striking its surface will pass through it and come to a focus on the macula or most sensitive spot of the retina, which membrane is to the eye what the sensitive plate is to the camera. The retina is the expansion of the optic nerve in the eye and conveys to the brain the impression of the image received upon it.

The crystalline lens is a gelatinous substance enclosed in a capsule or sac suspended in the eye just behind the pupil and controlled by a circular muscle called the ciliary muscle. Its form can be made voluntarily more or less convex so that both near and distant objects can be focused alternately on the retina and thus be distinctly perceived. This adaptation of the crystalline lens is what is called Accommodation.

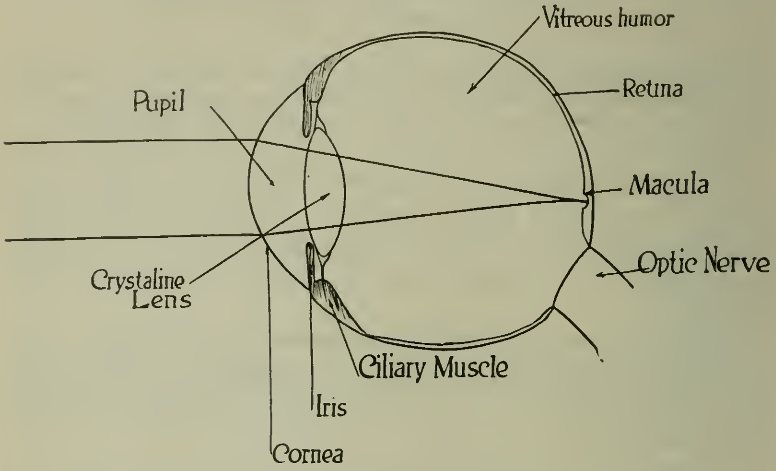


Fig. 1. Emmetropic, or normal eye.

Now, when the cornea is of the proper curvature and transparent, the crystalline lens in a normal condition and the eye otherwise healthy, parallel rays of light entering such an eye will come to an exact focus on the retina, and the person will

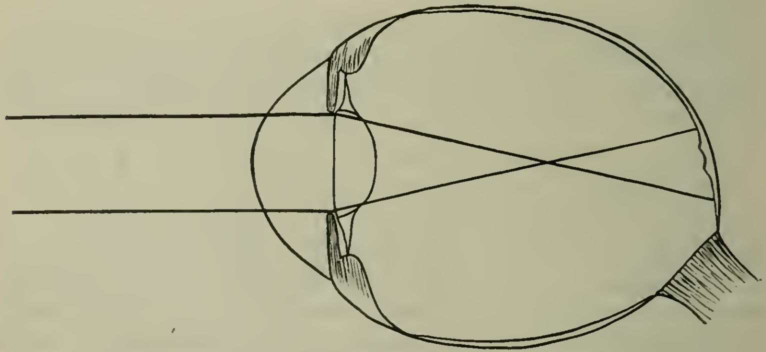


Fig. 2. Myopic, or nearsighted eye.

see objects distinctly without the aid of glasses. This condition of the eye is known as Emmetropia, or normal sight.

When the cornea is of too great a curvature, the eye-ball too long, or the crystalline lens too convex, parallel rays entering such an eye come to a focus before they reach the retina, and consequently make an indistinct picture upon it. Such a condition is known as Myopia, or near-sightedness, and is corrected by having the person wear near-sighted or concave spherical lenses.

When the cornea is of insufficient curvature, the eye-ball too short, or the crystalline lens too flat, parallel rays entering such an eye would come to a focus behind the retina and again cause an indistinct image to form upon it. This condition of the eye is known as Hypermetropia, or far-sightedness, and is corrected by the use of convex spherical lenses.

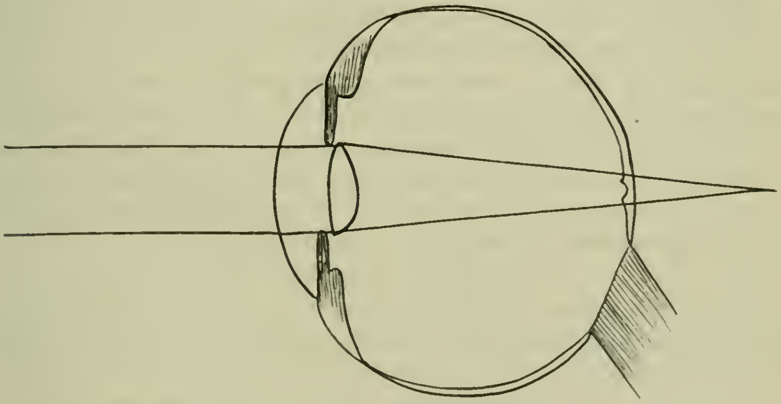


Fig. 3. Hypermetropic, or farsighted eye.

When the curvature of the cornea or the crystalline lens is greater in one meridian than in the others (or above the normal curvature), parallel rays entering such an eye do not all come to a same common focus on the retina. The rays of light passing through this greater meridian, will come to a focur in front of the retina, while those going through the other meridians will come to a focus on the retina; therefore, that part of the retina upon which fall the rays that have passed through the meridian of greatest curvature will perceive an indistinct image while the other part of the retina upon which the normal rays fall will perceive a distinct one. The image as a whole, however, will be an indistinct one. This condition of the eye is known as Astigmatism.

To learn whether the cornea or crystalline lens is of equal curvature and refraction in all meridians, the patient is asked to look at a chart consisting of circular discs made up of black parallel lines of equal intensity running in different directions, such as was devised by Dr. Paul Sartain, of Philadelphia, some five years ago, and lately published as something entirely new by a foreign authority.

If any disc appears more distinct than the others it indicates that the curvature of the cornea or the crystalline lens in the corresponding meridian is different from that of the other meridians.

If the rays of light passing through this particular meridian come to a focus before they strike the retina. the condition is known as Myopic, or near-sighted astigmatism, which is corrected with concave cylindrical glasses. If, on the contrary, rays of light passing through a particular meridian do not come to a focus by the time they reach the retina, the condition is known as Hypermetropic, or far-sighted astigmatism, which is corrected by wearing far-sighted or convex cylindrical lenses.

The object of the cylindrical glass is to correct the meridian of defective curvature only; thereby making it uniform and of equal refraction with the others of normal curvature.

A concave spherical lens, as you know, has the property of causing parallel rays of light passing through it to become equally divergent in all meridians, while a convex spherical lens has the property of causing parallel rays passing through it to become equally convergent and unite at a single point called the focus. The focus of a convex lens is behind the lens while that of a concave lens is in front. A cylindrical lens differs from a spherical one in that the cylinder has only one meridian of greatest refraction while the meridian at right angles to it is neutral. This meridian is called the axis and is so placed before the eye as to coincide with the meridian refracting rays of light normally.

A good comparison for a cylindrical and spherical lens is one Dr. Paul Sartain proposes, which is, that "a cylinder correspond to a section cut from the side of a stovepipe, and a spherical lens to a section from a ball."

Many persons have both myopia, or hypermetropia, and astigmatism in the same eye. For example, a person who is near-sighted and wears spherical lenses to correct his myopia, can acquire an astigmatism in addition to his myopia. A combined spherical and cylindrical lens is required to correct this condition, known as compound astigmatism. Such a lens is called a compound cylinder, because it combines both a spherical surface and a cylindrical one; one side of the glass being ground with a spherical and the other with a cylindrical curve.

A far-sighted or astigmatic person below the age of 40 years can see both far and near objects with the same glasses, because he has sufficient accommodation to see near as well as distant objects with his distant glasses alone. Certain near-sighted persons, however, require different glasses to see near and far just like a person having presbyopia, or old-sight, who requires one pair of glasses to correct his hypermetropia, or far-sightedness, and an extra pair to make up for his loss of accommodation, or presbyopia.

It is to that vast army of those requiring different glasses to see near and far that bifocals are designed.

There is a popular belief that bifocal glasses necessarily indicate that the wearer has reached that great bugbear of the human race, old age.

This is not a just belief, but is founded on the fact that many persons past middle life wear them to avoid the annoyance of two pairs of glasses. Now, in really anyone, no matter of what age, who is moderately near-sighted and astigmatic, for example, and consequently of weak accommodative power, unless he wishes to be burdened with two pair of glasses, must wear bifocals in order to see both near and distant objects distinctly.

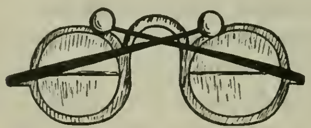
Another popular belief is that a person should put off wearing glasses as long as possible, as they are said to ruin the eyes, and that when one becomes accustomed to them it is impossible to see without their aid. This, of course, is an error, as a glass simply deflects the rays of light before they enter the eye that they may come to a focus at the proper point on the retina.

It is no more harmful to the eye to wear properly selected and fitting glasses than it is for a man to stand on a step or elevation in order to see something beyond the range of his height.

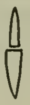
As to the inability of the wearer to dispense with glasses when once he becomes accustomed to them, it should be said that no harm can result from glasses that have been properly selected by a competent oculist, and made and fitted by a first-class optician; and, if one cannot get along without them once they have been worn, it means that the glasses have opened the wearer's eyes.

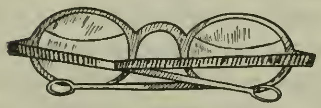
Again, many people are indifferent as to how they treat their eyes, and wear glasses that others have no further use for, not stopping to consider whether the glasses will do harm or not. I have known ladies who wore lorgnettes which belonged to their mothers or aunts, or glasses that had been worn by their brothers or sisters, yet these same ladies would become highly indignant if asked to wear their brothers' or sisters' cast-off hats or shoes.

About the worst case of abuse of the eyes within my knowledge was that of a boy who was taken to an oculist for treatment of his greatly inflamed eyes. Upon inquiring of the father how the boy had acquired this inflammation, he responded that his son had weak eyes, but as he objected to having him wear glasses some neighbor advised him, and here I quote his words: "To spit tobacco juice in the boy's eyes to strengthen them," which advice he had followed. When admonished for this, his wife, by way of reassurance said, "But, Doctor, my husband used the best tobacco he could get."

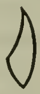


FRANKLIN–1777





SCHNAITMAN–1836



To return to bifocals, it may here be said that were first used by Dr. Franklin, who, while Minister to France, in 1777, had Secretan, a Parisian optician, make them for him. He was greatly pleased with his invention, and wrote that they helped him to win many arguments and thus accomplish his mission, which was to get the assistance of France in our struggle for independence, in which, as we all know, he succeeded. In one of his letters he wrote that when he wore these glasses he understood French much better.

The fact is that Franklin was very far-sighted, both mentally and optically, and while his mental hypermetropia permitted him to see far into the future, his sight did not permit him to see the expressions of French faces distinctly; with his bifocal glasses he could "see" what his French friends said, hence the above remark. He not only deserves the credit for their invention, but also that of having popularized them, for soon after many wore Franklin glasses, by which name they are still known.

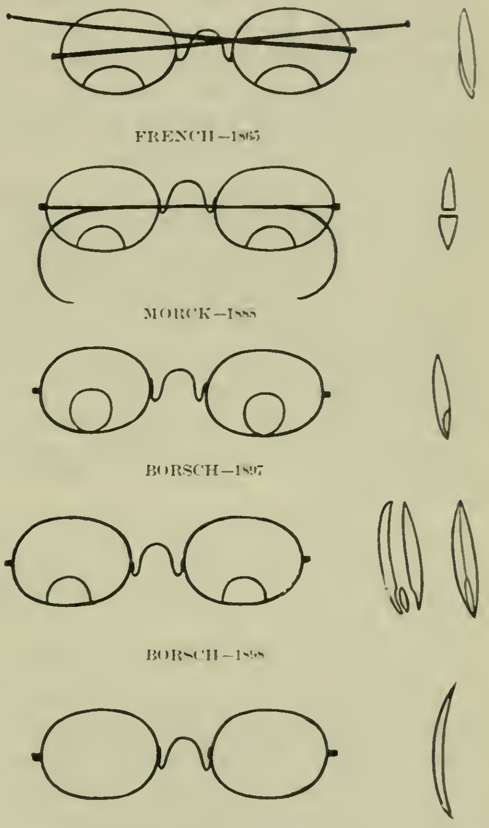


Fig. 4. Evolution of the bifocal lens

For some years "Franklin" or "Split" bifocals were the only ones used, and some are still in use in France to-day.

The objection to these lenses is that the line of junction between the near and far glass is very annoying; persons while wearing them have great difficulty in walking, owing to the prismatic effect which is due to their construction; the wearers of bifocals of to-day, especially the feminine ones, are unkind enough to term Franklin glasses "unsightly."

In 1836, Schnaitman, a Philadelphia optician, invented a ground bifocal lens. His invention consisted of grinding a weaker curve on the upper half of a lens of stronger curvature. The great objection to these glasses, however, was their extreme prismatic effect, which proved so annoying to the wearer that they were soon laid aside.

The next improvement we learn of was made in 1865, by a Frenchman, Secretan, of Paris, a relative of the original maker of bifocals, whose invention consisted in cementing a segment having a very sharp edge and a somewhat semi-circular form, on the lower portion of the distance lens. This small supplemental segment enabled the wearer to read with the lower portion of his glasses, while the upper part was for distant vision. This was a most decided improvement on the preceding forms, presenting the advantages of both, while avoiding many of their inconveniences.

In 1866, a Boston optician named Gregg, secured a patent on a form of lens very similar to this French one; that these French glasses were satisfactory is proven by the fact that some of them are still in use.

Cylinders had not yet been employed in bifocal lenses to correct astigmatism; however, in 1888, August Morck secured a patent on a bifocal lens that combined a cylindrical and spherical correction. This glass consisted of a distance lens of the sphero-cylindrical conformation desired; the lower portion was ground out in a semi-circular form and a segment of the appropriate reading combination was inserted in the place of the section removed. The two glasses were so adapted that the line of separation was least perceptible and had the distinct advantage of being exactly centered: that is, the optical center of each lens coincided with the geometric center of the corresponding lens. This lens fell into disuse when the French bifocals were made with sphero-cylindrical combinations.

Bifocals then reached so high a standard that oculists and opticians thought they had a lens which would forever remain an example of perfection. They had overcome the prismatic effect of the Schnaitman lens, the line of junction of the Franklin, and the prismatic effect of the Gregg glass, and thought the patient would forever now be content, but they had reckoned without two powerful hosts—vanity and sensitive nervous systems.

In effect, the lens that had come to be so much admired by all was gradually looked upon, by the ladies especially, as not so near perfection as it was at first thought to be; that line of junction of the near segment with its knife edge was not so imperceptible after all; in fact, when one knew it was there and had seen it a few times, it became quite noticeable; but what sealed its fate and made it an eyesore was the remark of some people, that it made the wearer look old.

In 1897, Borsch, of Philadelphia, devised a glass, which was termed the depressed bifocal. To make this lens he took a piece of Crown glass of certain index and ground it according to the required distance correction; in the lower part of this glass a circular or semi-circular depression of 17 millimeters in diameter was made into which he inserted a lens of higher index of refraction according to the strength required for near. The lenses were cemented together and gave a bifocal, the surface of which was but slightly interrupted. These lenses were further improved in 1898, by the same inventor, by enclosing the small segment between two plates of glass forming the distance correction.

The latter are very neat in appearance and delicate in construction, and combine most of the desirable features of bifocals; they are, however, in three pieces, cemented together with Canada balsam which, under certain conditions, is liable to become loose and clouded; then again, these lenses are quite expensive, so that they are within the reach of a limited number of persons only.

For a number of years the author has been endeavoring to devise a lens which would embody all the desirable features of a bifocal, from the oculist's, the optician's and the wearer's point of view. These desirable features are as follows: a bifocal having no perceptible line of junction between the near and far portions of the lens, no prismatic displacement, no cement to become loose or cloudy, a lens having the optical and geometric centers for the near and distance correction corresponding with each other, and, what is of no little importance, one that can be made by any lens grinder and at so modest a cost that it may be within the means of anyone requiring bifocals to gain a livelihood; and lastly, a bifocal that won't make the wearer look old.

This has been successfully accomplished, and the lens is made in the following manner: A depression is made in a piece of ordinary optical glass of refractive index of 1.53, and into this depression is placed a glass of higher refractive index, varying according to the strength of the lens required. These two glasses are placed in a special muffle, through which a current of electricity is made to pass, which causes the two glasses to coalesce or melt together without altering the indices of refraction of the component substances. This new piece of glass is taken from the muffle and given to the grinder, who grinds the required focus according to the distance prescription. The difference in density of the two glasses used will give the required near focus without any further grinding.
show you the result of these several years of work by exhibiting to you the solid invisible bifocal lens.

Book Notices.

The Telescope. Optical principles involved in the construction of refracting and reflecting telescopes, with a new chapter on the evolution of the modern telescope and a bibliography to date. By Thomas Nolan, M.S., A.M. (2d Edition, revised and enlarged, 16 mo., pp. 128.) New York: D. Van Nostrand Co. 1904. (Price, 50 cents.)

This volume forms one of the well known "Van Nastrand Science Series." The author has brought his subject up-to-date by adding a new chapter describing briefly the advances made since 1880, when the first edition appeared, and including a useful bibilography. W.

American Compound Locomotives. A practical explanation of the construction, operation and care of the compound locomotives in use on American railroads. By Fred H. Colvin. (8 vo., pp. 143.) The Derry-Collard Company, New York: The Locomotive Publishing Co. Ltd., London. (Price, $1.00.)

The railway engineers and the locomotive builders will find Mr. Calvin's work an exceedingly useful compendium of information pertaining to the compound locomotive as developed for use on American railways. W.

American Meter Practice. By Lyman C. Reed. 8vo, pp. 196. New York: McGraw Publishing Co. (Price, $2.00.)

The railway engineers and the locomotive builders will find Mr. Colvin's output of central electric power stations, and the electrical engineer will find it most useful should he have occasion to need a selection of the commercial meters, or to compare them in respect of efficiency and accuracy. W.

Franklin Institute.

[*Proceedings of the Stated Meeting held Wednesday, March 15, 1905.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 15, 1905.

PRESIDENT JOHN BIRKINBINE in the chair.

Present eighty-four members and visitors. Additions to membership since last report, twelve.

Prof. Lewis M. Haupt read a communication on "Tunnel Engineering with especial reference to the Simplon Tunnel." The paper was a brief historical sketch of the advances made in this branch of engineering by the introduction of improved drilling tools and high explosives.

Mr. Byron E. Eldred, of New York, was introduced by the Chairman, and gave an informal account of his "Method of Regulating Temperatures."

Mr. H. I. English, representing the Gray Telantograph Co., gave an account of the evolution of the telantograph since its first introduction in 1893.

These communications were freely discussed and were referred for publication.

The subjects of the remarks of Messrs. Eldred and English were referred to the Committee on Science and the Arts for investigation and report.

The Chairman extended the thanks of the meeting to the speakers of the evening and the session was adjourned.

WM. H. WAHL,
Secretary.

Committee on Science and the Arts.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, March 1, 1905.*)

DR. E. GOLDSMITH in the chair.

The following reports were adopted:

(No. 2310.) *Contributions to the Study of Documents, and Especially a Method of Quantitative Colorimetry.* Dr. Persifor Frazer, Philadelphia.

ABSTRACT: The contributions of applicant to the scientific study of documents, the determination of the individual character of handwriting and the detection of fraud and forgery, including in particular the wedge-shaped color prisms devised by applicant for aiding in the work of examining inks constitue the subject of this investigation. These contributions are contained in a published treatise of Dr. Frazer on this subject termed, "Bibliotics, or the Study of Documents," which the members of the sub-committee have examined, and express themselves satisfied that it is a clear, comprehensive and masterly exposition of this difficult subject, and a work of high scientific and literary merit.

The Sub-committee has also examined and tested the device of the color prisms submitted by applicant. These consist of gently-tapering wedges of tinted glass, which are placed over the writing, in a strong light and moved across it from the thinnest to the thickest end. While so doing there will occur two critical points; the first, that at which the ink marks appear of maximum darkness relatively to the background against which they are contrasted; the second is that at which the ink marks are no longer recognizable against the background; that is, they disappear.

The observation of one or both of these points, measuring carefully the distance from the point of the wedge at which they occur, gives data characteristic of the relative intensity of the ink mark tested.

In the opinion of the sub-committee, these prisms in the hands of one skilled in using them, are capable of giving approximate quantitative values to the relative color values of ink, and that the results of their use are of valuable assistance in the study and comparison of documents.

The sub-committee notes further that the mathematical discussion of the properties of these prisms, investigated by Prof. Geo. H. Hallett, of the University of Pennsylvania, shows that their selection and application are based on correct scientific principles, and this fact, therefore, increases the evidential value of the information obtained by their proper use in the hands of an experienced observer.

The investigators recommend the award of the John Scott Legacy Premium and Medal to applicant for his contributions to the science of bibliotics. (*Sub-Committee*, Joseph W. Richards, Chairman; Jos. H. Hart, Samuel P. Sadtler, C. C. Heyl.)

(No. 2331.) *Electric Protective Devices.* The Intern'l Burglar Immunity Co., Philadelphia.

Abstract: The system of applicant is protected by letters-patent of the United States, numbered 725,900, 730,422 and 735,324, and dated respectively April 21, June 9, and August 4, 1903.

It is designed for the protection of bank vaults, safes, and isolated places in general, and depends essentially upon the use of several circuits and the employment of relays in these circuits, which, by their becoming active or inactive, as the case may be, bring the alarm system into action.

The main claims of superiority over the existing systems are based upon the use of a separate current, whereby the system derives part of its protective qualities from the place protected, instead of from a central station. The system is further protected by current derived from an outside source; for instance, an electric lighting circuit, the tampering with which at any time causes an alarm.

The report finds the system to be well designed, and well adapted for the purpose for which it is chiefly intended, namely, the protection of isolated places. A Certificate of Merit is awarded. (*Sub-Committee,* Richard Gilpin, Chairman; Geo. P. Scholl.)

(No. 2281.) *The Art of Reducing the Attenuation of Electrical Waves and Apparatus.* Michael O. Pupin, New York.

Previously reported, and made the subject of a protest from Mr. C. J. Reed. The Sub-Committee suggested some minor amendments in its report, in consideration of Mr. Reed's criticisms, and re-ffirmed its previous conclusions. As amended, the report was adopted. The Elliott Cresson Medal is awarded to applicant. (*Sub-Committee,* C. C. Heyl, Chairman; E. A. Scott.)

The following reports passed first reading:

(No. 2340.) *Method of Color Photography.* Michael and Henry M. Miley, Lexington, Va.

(No. 2352.) *Phonosphere.* The Phonosphere Co., New York.

(No. 2358.) *Automatic Pistols.* The Colt's Patent Firearms Mfg. Co., Hartford, Conn.

(No. 2360.) *Method of Making Replicas of Diffraction Gratings.* Frederic E. Ives, New York.

Wm. H. Wahl,
Secretary.

JOURNAL

OF THE

FRANKLIN INSTITUTE

Erratum : *Art.* Borsch. A Solid Invisible Bifocal Lens. *Journal*, April, 1905, page 322. Third line from end of article after "any further grinding" interpolate

"Owing to the time already occupied, and which I think has been too much for so dry a subject as lenses, I will dispense with reading the formula for making the different foci required, which is only of interest to that extremely limited number of specialists who make optical glass, and will close my paper and . . . .

siderations in favor of and some opposed to the introduction of such apparatus. It is not often that the considerations on one side so strongly outweigh those on the other as is the case with the steam turbine.

The advantages claimed for steam turbines are many and the statement of a few of them may be of interest.

One generally considers the question of the steam economy of the turbine as compared with that of a steam engine as one of great importance. As much of the available data is difficult to compare, its discussion will be taken up later.

In addition to the steam economy, some of the advantages claimed for a steam turbine may be stated. The smaller size and weight of the steam turbine for the same output and the absence of reciprocating parts. make a unit requiring much less foundation, thereby materially reducing the cost of the installation.

You are all familiar with the drawing showing the relative space occupied by a Parsons Turbine and by a reciprocating engine unit of the same output. This comparison applies equally well to other applications of turbines.

I exhibit herewith some lantern photographs*

The first shows two pumps located in the coal mines at Bruay, in Northern France. These are fly-wheel condensing pumps, two complete pumping plants using the same fly-wheel. The space occupied is about 93 feet long, 28 feet wide and 19.7 feet high, with a foundation extending 13 feet below the pumps.

The second is a cross-section of the compartment showing that the side walls required were 6½ feet thick.

The third shows a turbine pump installed at the same place, the output of this pump being the same as that of one of the pumps in the previous diagram. The space required is 29.5 feet, by 10.4 by 13.1 feet, the side walls being 2.3 feet thick, the foundation being little more than a good floor.

The cost of two turbine pumps installed is less than one-half the cost of the two reciprocating pumps installed shown on slides 1 and 2.

A turbine pump supplying 2000 h. p. with feed water will occupy much less than half the floor space of a reciprocating pump of the same capacity.

The few bearings requiring lubrication in the majority of turbines and the ease with which the lubrication can be effected and controlled, and the fact that no oil need be used with the steam reduces the operating costs materially.

The ability to use high superheat, which is a particularly advantageous feature of some turbines, and to a less degree of others, should reduce the coal consumed, and the fact that the difficulties met with in using highly superheated steam in reciprocating engines are not met with in turbines, or to a lesser degree, has resulted in the use of superheaters in many turbine plants.

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*From Circular of Compagnie des Mines de Houille de Bruay, 1904.

The few bearings in a turbine outfit as compared with the many in a reciprocating one, the absence of sliding surfaces as piston, crosshead, valve mechanism, tend to a substantial decrease in operating expenses, and from such data as are available, this result is attained in practice.

The price one has to pay for a turbine set is large. Whether the increased price is justified must be determined for each case independently. Some recent figures on a plant of 1500 K.W. actual bids gave the cost of a reciprocating engine outfit from 25% to 50% less than the cost of turbine outfits, Three other bids on turbine units of 1500 h. p. varied about 24% among themselves.

It is probable that the difference in price between turbine and reciprocating engines will more nearly vanish as the making of turbines become standardized, and, in such sizes as are now standard, prices are as low or lower than for competing reciprocating plants.

To return to the question of efficiency, it seems reasonable to expect the efficiency of a turbine unit will be maintained with less difficulty than that of a reciprocating one. Turbine tests, repeated after a reasonable length of time, have given results practically the same as at the beginning. While this can be said of steam turbines, identically the same can be stated of reciprocating units that have been properly taken care of. It is, nevertheless, true that it requires less money to keep a turbine plant up to its initial efficiency.

This brings me to the question of efficiency that I would like to discuss at some length. Our ordinary conception of efficiency is either hazy or inexact. The off-hand statement that one machine develops a horse power on 15 lbs. of steam while another does it on 14 lbs, may be true and the second may be the more efficient of the two. One machine uses steam of higher pressure than the other, and this makes much less difference in the steam used per h. p. than is ordinarily supposed; or another works to a slightly greater vacuum, which makes much more difference than is usually supposed. Or it may be one used superheat of a greater amount than another. A rational basis for comparing two different types of machines is not easy to reach. The output of the machines divided by the heat available in the coal is fair *for the entire plant,* but when it comes to one portion of the plant, such as the prime mover, the comparison is not a fair one. The basis which is used here is the one which is coming more and more into use, and eliminates boiler, superheater, feed water heater, &c., and puts the output of the machine against the maximum amount of energy available between the conditions under which the steam is received by and discharged from the engine.

In Table I are the results of many tests made on steam engines. The headings of the table, until we come to those headed E, &c., are clear. The various engines are arranged with increasing value of E_5* This column is a measure of the amount of coal that would be used to run the engine if equally efficient apparatus, excluding the engine, was used in each instance, and is a fair measure of the value of the engine from the operator's standpoint, as it takes account of the conditions under which it is operated. The general range of the figures are worth noting. They increase continuously from the lowest to the highest, which is practically .21, without any very

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*The columns headed E_1, E_2, etc., are determined as follows: E_1, is Carnot's efficiency or $\frac{T_1-T_2}{T_1}$ where T_1 is the highest absolute temperature of the steam, and T_2 is the lowest. The number represents the maximum quantity of work that any ideally perfect engine could convert into work for 100 heat units supplied the engine.

The steam engine does not even theoretically act as the ideally perfect engine, and should convert into work, theoretically, the quantity shown under E_3. The value of the scheme and conditions under which the engine works (including pressure, superheating, vacuum, etc.) is shown by E_2 which is $\frac{E_3}{E_1}$. The value of E_3 is derived from the equation

$$E_3 = \frac{\gamma_1 + C_p\ (T_3 - T_1) - \left[q_2 + T_2\ \left(\int_1 \frac{cdt}{T} - \int_1 \frac{cdt}{T} + \frac{r_1}{T_1} + C_p\ log_e \frac{T_3}{T_1}\right)\right]}{\gamma_1 + C_p\ (T_3 - T_1) - q_2}$$

if the steam is superheated as it enters the engine and not superheated as it leaves.

If the steam supplied the engine is dry saturated, all terms containing C_p drop out. If the steam supplied is wet, so that x parts are steam and $1-x$ water, instead of $\frac{r_1}{T_1}$ read $\frac{xr_1}{T_1}$ and instead of γ_1, read q_1+xr_1, and omit all terms with C_p.

In this formula γ_1, is the total heat required to form steam at the pressure under which it is supplied (taken from the steam tables.)

great break. A comparison of this column with that marked steam per H.P. hour shows that for wide difference of E_5, the amount of steam per h. p. hour varies inversely with the value of E_5, while for small differences in E_5 this is not so, and the coal cost per H.P. may be less with the greater steam consumption.

While this value E_5 may be called the relative value to the consumer, the value of the machine as an apparatus for turning heat into work is more nearly represented by the column E_4, which shows the percentage of the available heat actually appearing as work.

For steam engines generally the difference between this figure and 100 is understood to be accounted for by initial condensation, by the passing of steam through the cylinder without doing any useful work. The value of this initial condensation is given, in some cases, in the column headed "Per-

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$C_p = .462 + 0.001525 p_1$ p being the absolute pressure. $T_3 - T_1$, is the amount of superheating. q_2 is the heat in 1 pound of water at the temperature T_2 corresponding to the back pressure.

$\int_1^{\cdot} \frac{Cdt}{T}$ is the entropy at the pressure of the steam.

$\int_2^{\cdot} \frac{Cdt}{T}$ is the entropy at the exhaust pressure.

r_1 is the latent heat at the steam pressure.

T_3 is the absolute temperature of the superheated steam. T_1 is the absolute temperature of saturated steam corresponding to the pressure.

All heat quantities and entropy are measured from 32°F. E_5 is the actual work done by each 100 heat units supplied the engine. Its value is found from

$$E_5 = \frac{2545}{W\,(r_1 + C_p(T_3 - T_1) - q_2}$$

Where W is the number of pounds of steam per indicated horse power per hour.

E_3 is what we ought to get from 100 heat units supplied and E_5 is what we do get and the efficiency of the heat transformation $E_4 = \frac{E_5}{E_3}$

Taking any one line of values for an example, we have

24.08, 94.5, 22.73, 53.5, 12.17

An ideally perfect machine could give for each 100 heat units supplied 24.08 [E_1] heat units as work. The scheme adopted for the given engine is only 94.5% [E_2] as good and if it worked perfectly as intended and under the conditions we have imposed on it, it should return 22.73 [E_3] heat units as work. Instead of working as well as the conditions imposed will allow, it only works 53.5% [E_4] as well and actually returns only 12.17 [E_5] heat units.

cent. of Initial Condensation." As a heat machine, therefore, the steam engine turns into work approximately 60% to 75% of the available energy, a large proportion of the balance being accounted for by the alternate condensation during admission and evaporation during the exhaust which goes on in every cylinder.

Referring now to Table 2, we have similar data for turbines of varying sizes. There are several things of note on this table; first the recent dates at which these data have been obtaind; secondly, the large number of experiments with superheat, as compared with the few in the steam engine table; thirdly, in the column E_5 the high range of values and the very few falling below 17%. A word of explanation as to the make-up of these tables. All data in parenthesis are based on the assumption of 90% mechanical efficiency and 90% electrical efficiency in the apparatus, or a total of 81% from what might be called the indicated power and the electrical output. This was done to bring the results to exactly the same basis for comparison.

The equivalent water consumption per I. H. P. is calculated, and is low as compared with steam engines of the same size and working under nearly the same conditions.

The value of E_4 does not differ very much from that for steam engines, and the fact that the metal parts of a turbine are not alternately heated and cooled does not seem to lessen greatly the loss which in reciprocating engines we attribute to initial condensation.

The reason for the high economy with steam turbines seems to be, first, the use of generally higher pressure; secondly, the use of superheated steam, both of which seem to be of less value than is usually attributed to them; and thirdly, the increased vacuum. The first condition would have the same effect both theoretically and practically in a reciprocating engine; the second theoretically is equally valuable in a reciprocating engine, but the practical use of superheat causes much trouble from variation of temperature, difficulty in lubrication and similar troubles; the third (low vacuum), theoretically is much less valuable in a reciprocating engine than in a turbine, because of the limited number of expansions valuable in the same engine.

To recapitulate:—The turbine occupies less room, requires less foundation, and can be operated with less lubrication and as little or less attendance. It is as efficient as steam consumption from a theoretical standpoint as well as from the owner's standpoint. Its depreciation should be as small or smaller than a reciprocating unit of the same size. The increased cost at present for the largest sizes will, in many cases, be justified, and the cost will certainly become as low as, or even lower than reciprocating engines, as the machines become standardized.

PROF. LOUIS C. LŒWENSTEIN:—In the present state of steam turbine building we must give most weight to the discussion of the scientific principles involved in this important type of motor. We engineers of course know that machine building, though widely extended practical experimenting has solved problems, with the utmost ease, which baffled scientific investigation for years. But this "cut and dry" method, as engineers ironically term it, is often extremely costly; and one of the most important questions of all technical activity, that of efficiency, should lead us not to underestimate the results of scientific technical work, particularly in such new territory as this.

Time and again it is urged that machine building be placed upon a practical experimental basis. Such a beginning would not be impossible, but it also would not be economical, and therefore not technical. Industry cannot be without scientific co-operation, not from idealism, but because under certain circumstances it is a "cheapest method" of accomplishing our purpose. We may call attention to the considerable sacrifices which engineers and machine builders have made in vain, due to incomplete understanding of the scientific principles involved in the problem undertaken. The great majority of those concerned will witness with indifference the economic loss of one of their number conducting a fruitless experiment, but to thoughtful men such an occurrence, which is unfortunately only too frequent, is regarded as a common loss, even without considering the fact that no one would like to be placed in a similar position. Steam turbine building especially affords numerous examples of the necessity of combining constructive ability with scientific principles. For instance, we might refer to the importance of previously determining the exact dimensions of a rotating wheel whose periphery almost reaches the velocity of a bullet, in order that the existing stress in the material do not at any place exceed the allowable limits Or, again, how disadvantageous it would be in the case of the horizontally rotating disc wheels that have lately come into use, and whose diameters attain considerable dimensions, to determine, experimentally, after first constructing, how much the discs deflect on account of their own weight, and how much they again straighten out, due to their centrifugal force; the latter a point of great importance, if we consider the scraping of the blades in the narrow clearance. What dangers the designer risks when he attempts the building of steam turbines without having exact knowledge of the phenomena of the so-called critical velocity. Finally, we could ask is it "economical" to even apply for a patent for a certain turbine system in which the greater part of the attainable work is destroyed before the steam has even reached the rotating wheel?

Obviously, on the other hand, we should not expect of the busy engineer in practical life that he should closely follow the complicated details of scientific work, but the fact still remains that he must be informed as to the results of scientific investigation. The intense competition to be expected between the various systems permits us to say that the designer, through the force of circumstances, is compelled to strive for the highest degree of practical and scientific perfection, in order to insure every possible success.

Within the space of a few minutes allotted to this paper we can only enter into a discussion of one of the scientific features of steam turbine design, but before doing so we might just mention a number of very important scientific investigations that must be made by the designer. The mere mentioning of these subjects will be sufficient, for their importance will be readily appreciated. Among these may be mentioned the flow of steam through orifices, nozzles and blade channels; the friction of rotating discs in a steam medium; mass balancing and the theory of the flexible shaft; critical velocity and period of oscillation due to elasticity; the deviation of rotating discs due to the bending of the shaft; the deflection of horizontally rotating discs and the action of centrifugal force upon them. We might multiply these subjects greatly, but enough are mentioned to show how necessary theoretical knowledge is to the designer of this important type of motor.

It is well known if steam, or in general any elastic fluid, flows through a simple orifice from a space of higher into one of lower pressure, the pressure in the orifice will decrease to about one-half the initial pressure, and there will occur in the stream after leaving the orifice strong accoustic vibrations. These vibrations cause a considerable loss of efficiency, and they must be avoided. De Laval has accomplished this by adding to the orifice a conically diverging nozzle in which the steam can continuously expand down to the back pressure.

Before the design of the nozzle can be undertaken we must fully understand the flow of steam in nozzles. Experiments were made to investigate this flow, and it would be well to describe briefly how they were conducted and the results derived.

An orifice of a nozzle through which the flow of steam was to be investigated was so mounted that a thin measuring tube could be inserted through the center of the opening. One end of this measuring tube was closed and the other end was connected with a pressure gauge. In the middle of this tube a hole is drilled at right angles to the axis. By means of a micrometer screw this tube can be moved in one direction or the other, so as to bring the measuring opening in any position of the nozzle axis. Experiments were first made to ascertain how reliable this method would be for the measurement of pressure, for as can be seen, it is not sufficient to place a measuring opening tangential to the flow of steam, but the position and the condition of the edges of the opening may be responsible for a disturbing effect. These experiments showed, however, that the readings taken in this manner could not materially differ from the true pressure. By now allowing steam to flow through orifices and nozzles of various shapes it was possible to plot a curve of pressures showing the variation of pressures throughout the length of an orifice or nozzle, and even beyond it. Some very interesting and important results were obtained.

The resistance to steam flow was first investigated, and after a great many experiments were made the conclusion was reached that it is allowable to consider the resistance to steam flow in a diverging nozzle as simple tube friction. With nozzles of small divergence and less than 2″ long and about ¼″ minimum diameter the loss of energy was about 10%, and with nozzles of greater divergence and about 4″ long and ⅜″ minimum diameter the energy loss was 15%. The decrease of velocity is about half as great.

Through partly closing a valve placed between a nozzle and a condenser we can produce any desired back pressure. In measuring the pressure in various parts of the nozzle we would note that the pressure first follows the line of free expansion and then increases according to the value of the back pressure in more or less sudden leaps. In these extraordinary heavy increases of pressure we find a realization of the theoretically derived "Compression Shock" of von Riemann. The steam particles possessed of great velocity strike against a slower moving steam mass and are therefore compressed to a higher degree. Such compression shocks will always occur when the nozzle has a greater length; that is, a larger cross-section divergence than the initial and the final pressures demand.

Other experiments were made on the flow of steam through orifices. These experiments gave the desired explanation of the so often spoken of phenomena of flow from orifices. As is known, Messrs. Mack and Emden have proved by means of photographs the presence of regular successive light and dark lines in a steam flowing from an orifice, which cannot be said to be anything else but acoustic waves; but as to the value of the existing pressures in this stream we were totally in the dark. Emden assumes that at places of compression the same condition exists as in the orifices. But he further says in contradiction to himself that there exists the same pressure at every place in the steam as exists in the surrounding atmosphere, and claims that there is a change of density. According to this for instance, for air, places of smallest velocity, that is smallest energy, must coincide with places of smallest temperature, that is, smallest potential energy, which is obviously impossible. By his calculation he further believed to have proved that the difference between the initial and the orifice pressures can only be used to produce the additional velocity of flow; the remainder of the available work is transformed into acoustic energy. The experiments lately made by Professor Stodola contradict these opinions; they prove that the steam first expands to the existing pressure before the orifice, that therefore the first rush (as is the case with suddenly releasing a compressed spring) too much potential energy is changed into kinetic energy. Only this excess changes into acoustic vibrations and is rechanged into heat at the rim of the stream by friction and eddy currents. The oscillations occur in the axial direction as well as in the radial. The stream flows at the pressure of the orifice into a region of much smaller pressure, begins therefore to expand in a radial direction. The resulting drop of pressure accelerates the particles also in the axial direction. Steam flowing from a diverging nozzle shows the same phenomena as from a simple orifice. With varying back pressure it was found that the steam on leaving the nozzle gave very regular acoustic vibrations, but it was possible to so fix the back pressure that every trace of a vibration disappeared.

From these experiments we finally arrive at the fact that the steam in a nozzle expands nearly adiabatically independent of the back pressure. If the steam flows into a place in which a back pressure exists exactly equal to the final pressure of expansion then the pressure in the stream is not changed at all. If the pressure is lower, acoustic vibrations occur, as with a simple orifice; if the back pressure is too high, a steam shock occurs with more or less drawn out oscillations. By entirely filling out the cross-section of a diverging nozzle, a vibration is made difficult, if not entirely impossible. We can hardly go wrong if we say that the drawn-out vibrations occurring in a simple orifice are caused primarily by the sudden difference of pressures at the stream's rim and the surrounding atmosphere, which the stream quickly spreads. There is, therefore. the possible assumption that when vibrations still occur in the interior of the nozzle, the stream has detached itself at such places from the wall.

If we construct the nozzle according to the formula of Zeuner, the final pressure will be greater than the prescribed back pressure, because friction transposes the kinetic energy into heat, and the expansion line will rise above the adiabatic. A nozzle calculated therefore according to Zeuner would actually be somewhat too long. This fact was soon recognized. To correct this Rateau, and after him Delaporte, proved by experiments that the pressure of a stream on blades or suitable plates decreased very little if the nozzles were made shorter; that is, the stream is allowed to flow out at a slight overpressure, and recommended this to be done. It remained for

Stodola to prove by his experiments just mentioned that violent acoustic vibrations would then take place in the stream, and that these must be avoided. It is important to make the nozzle dimensions suitable to the assumed back pressure. Before correct nozzle dimensions can be determined we must know from experiments the probable steam friction loss in the nozzle and then the design of the nozzle is easily accomplished.

We shall not enter into the discussion of any of the other mentioned features of the steam turbine, but will say in conclusion that the development of the steam turbine within the last few years has been remarkable. It has already reached a position not only of equality with the best modern engines, but its high efficiency, its lower first cost, smaller size and cost of operation have placed it in the very foremost of steam engine practice. It is the belief of engineers now engaged in steam turbine designing that as soon as they have solved some of the important phenomena connected with steam flow that the turbine will entirely outrank the reciprocating engine.

In the steam turbine we are confronted with an entirely new series of phenomena. The knowledge of steam accumulated by familiarity with the reciprocating engine is of little use in designing this newest yet oldest of prime movers. Nor can the cut-and-dry methods that have brought the reciprocating engine to its present, and it may be said, its final stage of excellence, be employed in the steam turbine. Modern commercial conditions are such that design must be based on ascertaining physical laws.

This rapid advance has necessitated the re-investigation of steam from the point of view of velocity instead of pressure, of kinetic energy instead of potential, and the friction of rapidly moving bodies against a vapor instead of a lubricated surface, of the balancing of parts so that they shall revolve about their center of gravity, and of numerous other questions which are but beginning to make themselves felt.

The available data are few, and practically all of the information is scattered through the pages of German and French scientific periodicals and a few scientific books.

Mr. J. A. Lafore.—In the very interesting table presented by Professor Spangler, showing the relative economies of various engines and turbines, I would call attention to the fact that the actual comparison between different types of apparatus in the matter of economy is clearly indicated by the horse power of any particular unit as compared with the horse power of the other units at the same position in the list. It is of course to be expected that the economy of an engine or turbine increases with an increase in size, and if the 300 H.P. unit of one type is of the same economy as a 1000 H.P. unit of another type, it is reasonable to suppose that the former represents the most economical type. I wish to call attention to the position of the De Laval apparatus in this list, particularly the 150 H.P. unit, which you will note stands side by side with other apparatus of many times its capacity.

I shall describe briefly the general construction of the De Laval Steam Turbine, but wish to speak particularly of the application of the turbine for driving apparatus other than electrical machinery.

The steam turbine is, of course, best adapted for furnishing power where the conditions require comparatively high speed, and where rotary motion is desired. These conditions are met with in electrical generators, and for this reason the greatest development in the application of the steam turbine has been in the driving of direct-connected electrical machinery. The high rotative speed does not detract from the efficiency of the generators, though, of course, in direct current apparatus the matter of satisfactory commutation must be considered, which makes it inadvisable to drive direct current machinery by certain types of high speed turbines, to which alternators can be attached satisfactorily. In comparing the advantages of the single wheel and multiple wheel turbines, this point should be considered, as a single wheel turbine with a reduction gearing readily permits of connection to direct current generators at practically standard speeds. Speeds sufficiently low are not readily secured with multiple wheel turbines, without impairing their efficiency.

In addition to driving electrical generators, the turbine is now used for many purposes, and will no doubt in the future be developed for many different classes of service. It is probable that we may look for great development in steam engineering along this line, and the De Laval Steam Turbine Co. has already a large number of turbines in operation direct connected to pumps and blowers, and also driving line shafting by means of belts.

The impact turbine, devised by Branca, consisted of the vaned wheel, upon which steam issuing from an orifice impinged. This type of wheel, now generally known as the "De Laval," depends largely for its efficiency on the diverging nozzle of De Laval, which has been so ably discussed by Dr. Lœwenstein, and which is now used in one form or another in many types of turbine.

Figure I shows a standard De Laval nozzle set in turbine case with valve seated against the entrance to nozzle. The steam in case passes through the nozzle, impinging against the buckets as shown. If the nozzle is properly designed the steam leaves the exhaust end of the nozzle in a nearly parallel jet, moving in the direction of the axis of the nozzle at the point of exhaust, and has little tendency to move in any other direction. The steam is expanded in the nozzle between the working limits of pressure, the available potential energy between these limits being changed to kinetic energy, and the kinetic energy transferred to the turbine wheel. The steam issues from the nozzle at a very high velocity, 4500 feet per second being secured under favorable conditions in practice.

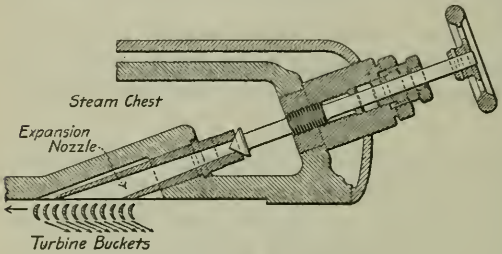


Fig. 1.—De Laval Nozzle.

While a velocity of over 4,000 feet per second can readily be secured from the exhaust of the diverging nozzle, the conversion of the kinetic energy in the steam to useful work presents engineering difficulties of considerable proportions. In order that all the work of the steam shall be given to the buckets on the moving wheel, it is obvious that the velocity of the steam on leaving the wheel must be nil. relative to the nozzle, and it is easily seen that this is the case when the speed of the wheel is one-half that of the steam, presuming that the steam impignes on the wheel in a direction at right angles to the face of the buckets, and in the plane of the wheel. As the nozzle is set at an angle of about 20° to plane of wheel, the speed of wheel should be actually somewhat less than this. The high peripheral speed necessary to secure economical results necessitates great care in designing the turbine wheel. The De Laval wheel is of the kind shown in Figure 2. The wheel is a nickel steel forged disc, very thick at the center and tapering towards the edges. The factor of safety at normal speed is about 8. It is carefully balanced, and the rim contains a number of milled slots with holes drilled at their bases, in which the vanes or buckets are held. The buckets are made of drop forgings of steel with bulb shanks, and are fitted in the rim of the wheel by being driven in from the side. The outer wedge of the bucket is enlarged to rest against the next bucket, so that a complete set of buckets make a ring forming the outer circumference of the wheel. The massive hub of the wheel is constructed solid in all of the larger sizes, and the shaft is built in two pieces, and bolted by a flanged connection to the wheel. In the smaller machines the shaft passes through the hole in the center of the wheel.

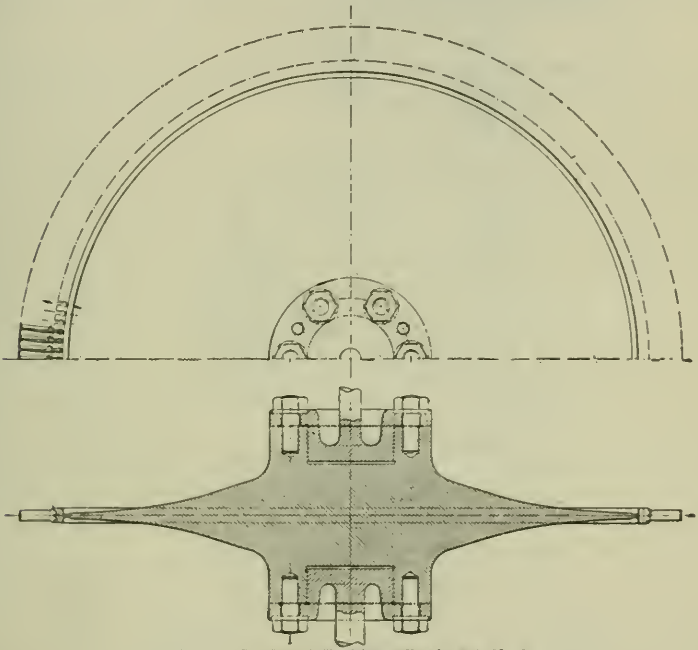
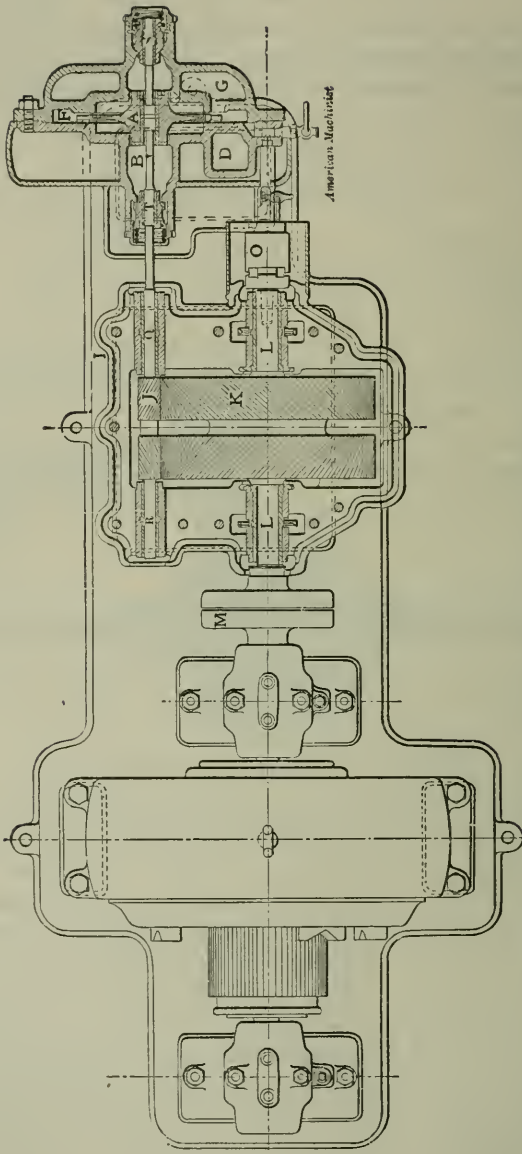


Fig. 2.—De Laval Turbine Wheel, 300 H. P.



American Machinist

Fig. 3.—Sectional Plan De Laval Turbine Dynamo, 30 H. P.

The wheel revolves free, in a cast-steel case, there being a clearance of about $\frac{1}{8}''$ to $\frac{1}{4}''$ between the nozzles and the buckets.

A 300 H.P. wheel is about 30″ in diameter between centers of blades, runs at approximately 10,600 revolutions per minute, and the peripheral speed is therefore about 1,600 feet per second, or about eighteen miles per minute.

The high speed necessitates the use of some method of gearing down the speed to bring it within reasonable limits.

One of the essential features of the De Laval turbine is the flexible shaft. It would be impossible to revolve the wheel at the very high speed necessary for good economy without some means of providing for the fact that the center of gravity of any wheel, no matter how carefully constructed, is not exactly coincident with the geometrical center. The flexible shaft provides a simple method of securing this result, the shaft being supported by two bearings, "Q" and "S" in Figure 3, at considerable distance apart, and the wheel "A" allowed to seek its own center by the elasticity of the very thin shaft between these points. It will be noted from the cut that there is a floating bearing "T" at the point where the shaft leaves the wheel case, this bearing serving as a packing box and in no way supporting the shaft. These packing bearings are of brass and are lined with white metal, as are the other bearings.

The teeth of the pinion "J" are cut in the shaft, in large sizes, each tooth forming a complete spiral, so that every tooth is in service all the time. The gear wheels, "K," are of cast-steel faced with a steel forged band, in which the teeth are accurately cut. It will be noted that the pitch of the teeth is exceedingly small, being in the three-hundred-horse-power size only about one-quarter of an inch. In the larger turbines the pinion and gear wheels are in the ratio of approximately one to twelve, and in the smaller turbines in the ratio of one to ten. The peripheral velocity of the gear wheel is about 6000 feet per minute. On turbines of seventy-five horse power and above, a double gear is used, this decreasing the side thrust on the high speed shaft. These gears will operate for many years without wearing, the European De Laval Companies having had them in service as long as eight or nine years, and no gear wheels have, up to the present time, any marked deterioration.

All bearings consist of brass sleeves lined with babbitt metal set in ground boxes in the turbine frame without any means of adjustment. Any bearing on the turbine can be removed and a new one substituted without removing the shaft.

The governor is of the centrifugal type, consisting of a split cylinder operating on two knife edges, the action of the centrifugal force being resisted by a double spring. The moving parts are light and the friction exceedingly small, which results in very quick action. The governor valve is a double-balanced poppet valve. There is also provided in condensing turbines a valve in the wheel case, upon which the governor acts when the turbine, due to suddenly throwing off a heavy load, tends to race, this valve breaking the vacuum and reducing at once the speed of the wheel. I believe that better regulation is secured by a combination of this governor and the vacuum valve than is possible with any other type of condensing turbine or compound engine.

The centrifugal pump, which offers many advantages not found in other types of pumps, requires a higher peripheral velocity of runner for satisfactory operation, and is therefore particularly well suited for direct connection to steam turbines. The De Laval Steam Turbine Company manufactures the pump and steam turbine complete as one unit. The standard pumping unit consists of the turbine with geared down shafts, which drive the pump runners, but the Company has developed a rather remarkable pump for high pressure service. This pump is compound, two runners being used in series,. one being coupled direct to the high speed turbine shaft and the other to a shaft geared down and operating at a lower speed. The low speed runner, which operates in a separate case, entirely independent of the high speed part, does only about 20% of the work, serving merely to deliver the water to the high speed pump. The high speed runner, which is remarkable because of the speed at which it operates and its size, receives the water from the other runner and delivers it under heads as high as 700 feet. The high speed runner, however, will not lift water, and it is therefore necessary to use the low speed runner to secure the necessary suction, unless water is delivered to the pump under some head.

Figure 4 shows, full size, a 60 H.P. high speed runner, which handles 250 gallons of water per minute against 700 feet head. and operates at a speed of 20,000 R.P.M.

The economy of space in the installation of a pumping unit is frequently of considerable importance, and in the feature of small space occupied, the steam turbine pump stands entirely alone. Figure 5 shows a standard pumping engine, made by one of the largest manufacturing companies in the country, having a normal capacity of 1800 gallons of water per minute against a pressure of fifty pounds, and a De Laval Steam Turbine pump of the same capacity. The illustration shows only the difference in floor space required,—the difference in size of foundation is equally marked.

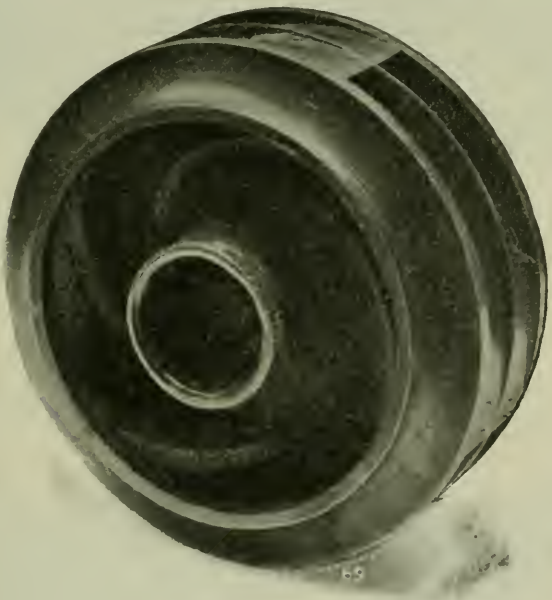


Fig. 4.—Full Size De Laval High Speed Pump Runner. 250 Gallons Per Minute. 700 Ft. Head. Speed, 20,000 R.P.M

It may be of interest to the members to note a test of the centrifugal pump and steam turbine when operating under ordinary conditions, with a comparatively low vacuum, as shown by the test of Messrs. Denton & Kent. The curves (Fig. 6)

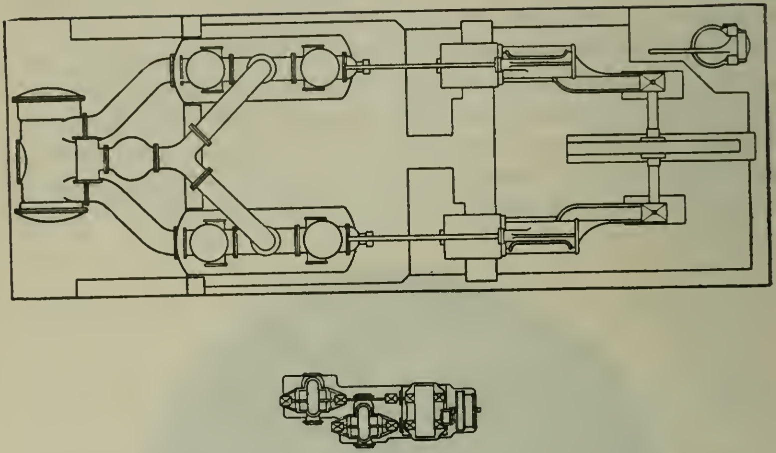


Fig. 5.—A Corliss Pumping Engine and a De Laval Steam Turbine Pump of the same Capacity, both Drawn to the Same Scale.

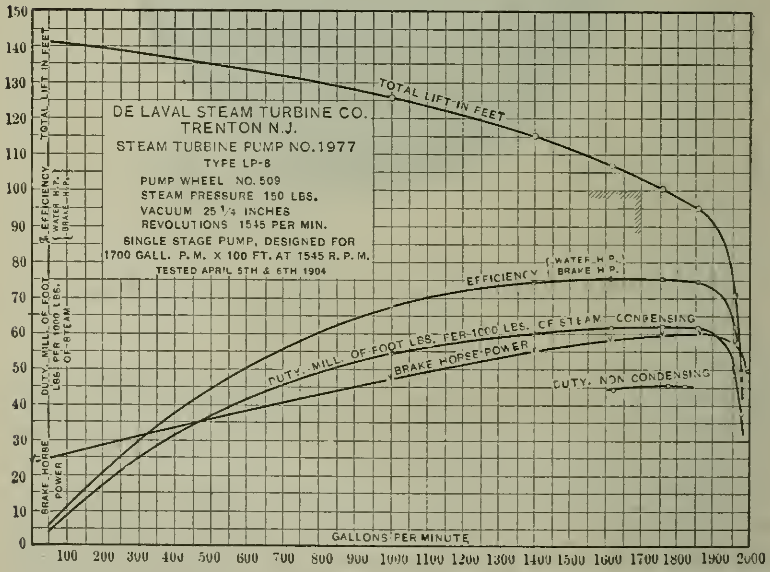


Fig 6.—Characteristic 55 H. P. Turbine Pump. Steam Pressure 180 Lbs. Vacuum 25¼ Inches.

show clearly the results of this test. It should be noted that this is a comparatively small unit, being only of 55 H.P. capacity. It is shown in Figure 7.

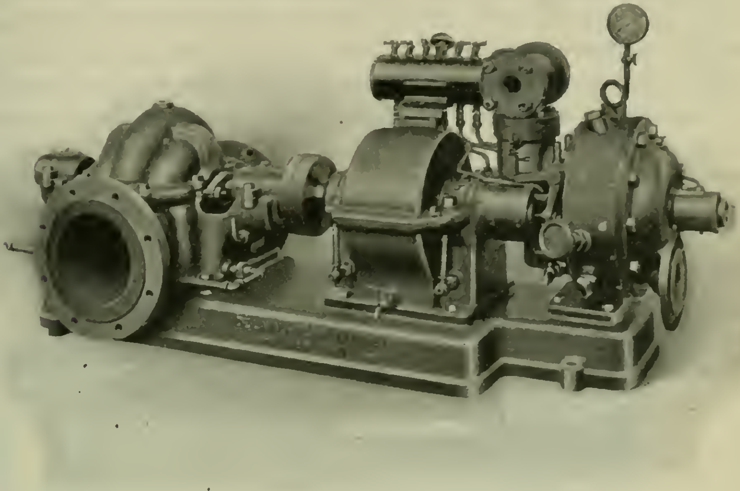


Fig. 7.—De Laval Steam Turbine Centrifugal Pump. 1700 Gallons per Minute. 100 Ft. Head.

Figure 8 shows the general construction of pump furnished for direct connection to turbine. The bearings are ring oiling. There is a drip chamber between packing box and bearing and the upper half of case is removable. Runner is made of bronze.

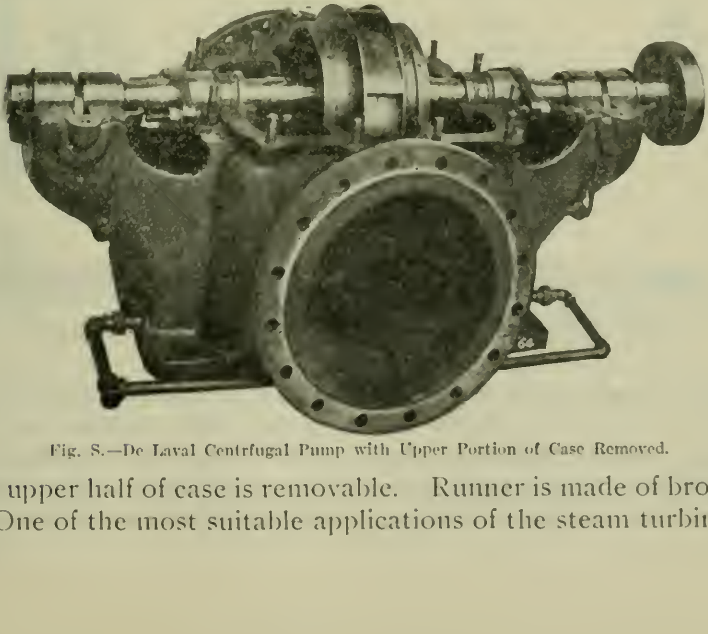


Fig. 8.—De Laval Centrfugal Pump with Upper Portion of Case Removed.

One of the most suitable applications of the steam turbine is for driving blowers and exhausters, and the De Laval Company are now building many turbines for this purpose. With reciprocating engines, in order to secure the pressures desired for many classes of work, the blowers must be driven at a speed which ordinarily makes it necessary that belt connections be used. In the smaller sizes, in fact, where the blowers are used in connection with water gas plants, a counter shaft is required to secure the proper speed with a reciprocating engine. Where connected to a turbine, they are mounted directly on the same base, and form a very compact unit. To indicate the difference in size between the old form of apparatus and the turbine-driven blower, I have shown to scale in Figure 9 a portion of the Point Breeze plant of the Philadelphia Gas Co., where three engines and belt-driven blowers, having a total capacity of 60,000 cubic feet of air per minute in the three machines, are installed. The small De Laval outfit to the left has been recently placed to increase the capacity of this plant. This steam turbine blower is about half the capacity of the other three units

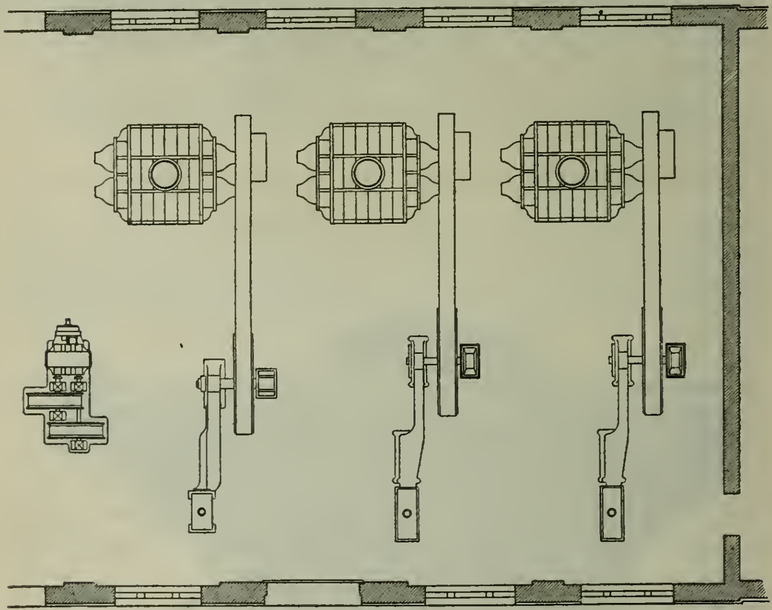


Fig. 9.—The Small De Laval Steam Turbine Blower Shown in the Lower Left-hand Corner has a Capacity Equal to one-half that of the three Engine-driven Blowers Combined.

combined. In other words, with two De Laval turbines occupying a floor space of 300 sq. feet, the same result would be secured as with the three belted blowers and engines occupying a floor space of 3,000 sq. feet.

The steam consumption of the turbine per H. P. is somewhat less than half that of the reciprocating engine units in this particular installation. A photograph of this turbine blower is shown in Figure 10.

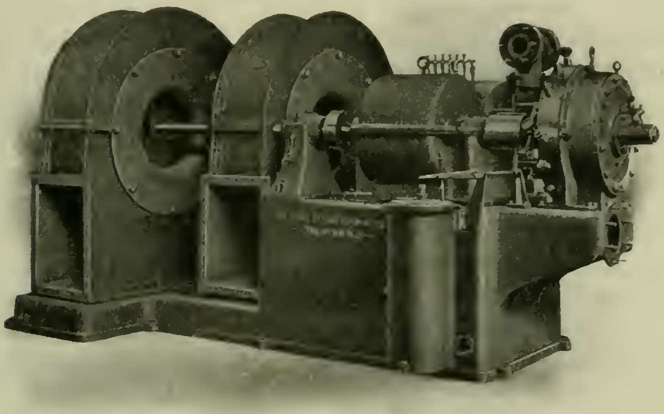


Fig. 10.—De Laval Steam Turbine Blower.

Mr. Richard H. Rice.—The Curtis turbine has been extensively described in the technical press and in papers read before various Engineering Societies, therefore no extended description need be given here. I will only give enough particulars to render its distinctive features clear in comparison with other turbines.

It uses expanding nozzles to impart velocity to the steam before entering the buckets. (Like De Laval; unlike Parsons and Rateau.)

It uses two or more rows of revolving buckets to receive the steam from the nozzles and convert the steam energy into rotational motion. (Distinctive.)

It has several stages, each one consisting of nozzles, combined with two or more rows of moving buckets and their corresponding stationary buckets. (Distinctive.)

It has a very moderate number of stages, two to six. (De Laval, 1; Zoelley, 10; Rateau, 25; Parsons, 40 to 50.)

It is governed by discharging steam at full pressure through the proper number of nozzles to suit load requirements without throttling. (Distinctive. Others throttle, except Parsons, who governs by varying the amount of periodic puffs.)

It employs wheels of considerable diameter, occupying short lengths of shaft, with moderate bucket speeds. (De Laval and Zoelley, high buckets speeds. Zoelley, Parsons and Rateau long shafts.)

It uses only a small arc of admission to the first stage. This admission arc is divided in the larger machines into two parts. The active nozzle forms a continuous belt discharging steam in such a way as to produce an uninterrupted band of steam entering the buckets and this band is varied in width by the governor in accordance with load requirements. (All others but De Laval use the entire circumference, and De Laval uses isolated single nozzles.)

All sizes developing any considerable power have vertical shafts. (Distinctive.)

Briefly stated, the vertical form of Curtis turbine, which include all sizes of 500 K.W. capacity and upwards, consists of a turbine with a vertical axis having two or more stages and taking steam at pressure from 100 to 200 lbs. per sq. inch, and exhausting either into the atmosphere or into a condenser. Above the turbine is mounted an electric generator directly on the same shaft. The shaft is supported by and rotates upon a frictionless fluid step bearing. The governing is done by means of individual valves, each controlling one or more nozzles, these valves being mounted on the top head of the turbine and actuated by a suitable mechanism which is influenced by a governor placed on the top end of the shaft, which governor regulates the speed by opening one or more valves as the requirements of the load may dictate.

The sizes below the 500 K.W. capacity are of the horizontal form and of various designs, to suit the special requirements of the services for which these turbines are intended. Those up to 75 K.W. capacity are of the overhung type, consisting of one or more wheels keyed to the end of the shaft and surrounded by a suitable casing. These over-hung shaft turbines have throttling piston valves directly controlled by a governor on the end of the main shaft. From 75 K.W. to 300 K.W. capacity the turbine has four bearings, with separate turbine and generator shafts connected by a flexible coupling. These four-bearing sets have governors of the same type as those used on the vertical machines.

Referring to the literature above quoted for further particulars and description of mechanical details, I will call your attention to various applications of Curtis turbines which have already been made.

The turbine, by virtue of its high speed, lends itself readily to connection to electric generators, and only one of the various types now on the market requires gearing to reduce the speed of its shaft to a suitable figure for connection to the generator. All others have the generator mounted on the turbine shaft or a continuation of it, and move at the same speed.

There are, however, considerable differences in speed of the various types, and among them the Curtis speeds are the lowest. This fact permits the generator end, as well as the turbine end, to be very conservatively designed, and as a matter of fact the generators used with the Curtis turbines are among the best ever constructed by the General Electric Company. This has an important influence on the results obtained by the operation of these units, since highly efficient generators mean that more of the energy contained in the steam is delivered at the switchboard in the form of electrical power. The generators have very conservative constants and a considerable overload capacity, which characteristics fit them for action with all varieties of load and for all purpose demanding flexibility, good regulation and steadiness of operation; and combined with the small internal friction of the vertical type, ensures the maximum conversion of energy in the steam into useful work.

These turbines, having so moderate a speed, are peculiarly adapted to direct connection to turbine and centrifugal pumps, air compressors and other high speed machines, and considerable progress has been made in such directions, which, however, will be the subject of description elsewhere and at a future time.

Ordinarily, since the turbine derives great benefit from the production of a good vacuum at its exhaust outlet and is able to utilize such a vacuum to a greater extent than any other heat engine, and since it can deal with high pressures in the inlet, it is assumed that such conditions are necessary to its proper performance.

The fact is, however, that the turbine can be economically operated as a non-condensing engine, and many turbines of the Curtis type have been built and are operating non-condensing with satisfactory results. In economy it compares with the older type of engine with which it is in competition, while the almost automatic operation of the turbine, its small floor space, its quiet operation and the absence of oil in the steam all make it a desirable substitute.

Another promising field for the turbine, which has been pointed out by Mr. W. L. R. Emmet, is in utilizing the exhaust from reciprocating engines, operating either condensing or non-condensing. To provide further power, the turbine exhaust is turned into a condenser, furnishing a high vacuum. The Curtis turbine is very responsive to the influence of a high vacuum and gains rapidly in efficiency as the excellence of the vacuum increases. It is therefore very appropriately used in this way, and in connection with engines discharging steam and atmospheric pressure the turbine will more than double the useful effect of the steam. For instance, when used in connection with an engine exhausting at 24″ vacuum, about 20% additional power will be realized.

It will be seen that the turbine in this way opens up a most promising field for the improvement of existing plants, enabling the output to be largely increased with a small capital outlay and reducing thereby the operating costs.

Various special applications have been made from time to time of Curtis turbines, owing to the peculiar adaptability of the turbine set for use in locations where weight and the cubic space occupied cut an important figure with turbine sets of small size. I will only instance one or two applications.

Many sets are in use for generating the current used in lighting trains. In these cases the turbine set has been installed on the buffer beam of the locomotive, on top of the boiler or in the baggage car. In the first two cases the steam pressure used is that of the boiler, say 175 to 200 lbs., and in the case of sets in the baggage cars the pressure is the same as that in the steam piping conveying steam through the train for heating, say 50 to 80 lbs. In either case, the sets are used in conjunction with storage cells, which furnish current when the train is in the station and the locomotive is being changed.

Some work has been done in developing headlight sets, using for this purpose turbine sets of 1¼ K.W. capacity. This set is mounted with the headlight on the usual bracket immediately in front of the smokestack.

These applications will be enough to indicate the great flexibility and adaptability of the turbine for use in severe and unusual locations.

Since the steam which has been passed through the turbine is entirely free from lubricating oil, this fact directed attention at the outset to the advisability of condensing this steam in surface condensers, in order that pure feed water might be secured for the boiler and the water consumption, especially in cases where feed water is impure or expensive, might be kept as low as possible, using as cooling water any inferior source of water supply which would in general cases be unsatisfactory for boiler purposes. For instance, in cities on the seaboard, the supply of fresh city water could be reduced to a minimum and the circulating water could be salt.

Due to these considerations all the first Curtis turbines were fitted with surface condensers.

Since the turbine utilizes the expansion of the steam completely while the reciprocating engine does not, for reasons well known, it was found early in the developmental period that it would pay to put in large condensers and obtain much better vacua than usual. The condensers do not, however, need to be very much larger, since turbines are free from air leakage, which it is almost impossible to prevent in engines having a considerable number of piston and valve rod stuffing boxes, and also because, oil being absent, the cooling surface retains its efficiency indefinitely.

The use of dry air pumps, already in vogue by condensing engineers in cases where the best results were desired, has been quite generally extended to turbine condensers, and in case the temperature of the cooling water is not too high, vacua of 28″ and 29″ are readily produced, while the power required to drive the pumps for this purpose varies from 2½% to 4%, depending upon the design of the circulating water passages.

Other types of condensers are gradually coming into use on our turbines, in cases where an abundant supply of good water is obtainable, one of which types is the jet condenser, running with injection and dry air pump. If the proper allowances are made in proportioning the dry air pump for the dissolved and entrained air in the water, and if the water is permitted to settle and discharge the entrained air before being pumped into the system there will be no difficulty in obtaining good results.

The same remarks apply to siphon condensers, and there will be, with proper proportioning, no difficulty in obtaining first-class vacua with this type.

In cases where water is scarce, a cooling tower may be used. I have obtained guarantees of 27″ with these, used in connection with turbines for summer temperatures in Northern states, and with condensing outfits proportioned to meet these guarantees expect to realize 28″ during at least five months of the year. Experience will soon be available on at least one of such installations.

The Curtis turbine, on account of the originality of its construction, has naturally exercised an important influence on power house design. This influence has been exerted in the directions of treatment of accessories, arrangements of boilers, and floor space.

With the adoption of vertical shaft turbines, which only require a low circular foundation, four to six feet in height, the practices existing in a reciprocating engine station, as to fixing of floor levels and provision of basements, no longer obtained. It was recognized that the basement and engine room floor could, in many cases, be advantageously combined. This arrangement at last gives the accessories of the turbine their proper place as an integral and necessary part of the apparatus of the station, and also necessitates (what needed to have been done before) the placing of this apparatus on the principal floor level, with good light and perfect accessibility, so that proper care and attention must of necessity be given.

Because of the small floor space occupied by the turbine per unit of power, the usual arrangement of the boilers in single or double lines parallel with the engine room, was found to leave too much unoccupied space in the latter. Arrangements therefore naturally came into vogue whereby the boiler room space is more advantageously disposed, either in the form of a double-decked boiler room, in particularly crowded locations, or in the arrangement of boilers in rows perpendicular with the axis of the engine house, so that each perpendicular row of boilers would have sufficient capacity to supply one turbine. This latter arrangement is that most generally useful, and splendid stations built on this plan may be seen at Chicago and Boston.

Recently, in some stations, accessories, such as pumps, condensers, heaters, etc., have been placed in another room apart from the turbine, so that some stations are now divided into three rooms, the boiler room, the turbine room and the condenser room.

In lighting stations, moreover, the switchboard has become extensive and important and questions of safety and convenience dictate the placing of all these parts in a separate house.

Modern station design with turbines has therefore proceeded along lines of specialization and the confinement of zones of trouble within very narrow limits, the apparatus outside of which is extremely unlikely to be simultaneously affected.

MR. JOHN H. MACALPINE then made the following remarks on the "Relative Economy of Reciprocating Engines and Turbines for the Propulsion of Ships."

Founding on the data available up to the time of printing the Report, which Admiral Melville and I made to Mr. George Westinghouse, on Steam Turbines, especially with regard to their application to the propulsion of ships, we stated:—

1st. We are inclined to believe with Professor Rateau that the lower limit of speed (of ship) for the effective use of the turbine is not under twenty knots, and we think it may possibly be higher.

2. That the consumption in small warships at half speed is nearly twice as great with the turbine as with the reciprocating engine.

3d. No allowable addition of cruising turbine can come near making the pressure gradients as small as would be required to maintain full power economy at half speed.

These conclusions seem to be confirmed by the most recently published data obtained by the British Admiralty trials of H.M.S. Amethyst, taken in conjunction with the trials of H.M.S. Usk, the data for which were given to us by the British Admiralty. The trials of H.M.S Amethyst and Topaze are published in *Engineering* of November 18th, 1904.

The results of the Amethyst are better than those from the previous turbine ship, H.M.S. Eden; partly, we understand, from a general improvement in the design, and at low powers from the introduction of two cruising turbines through which steam has to pass in succession before reaching the H.P. and two L.P. turbines; the H.P. and L.P. turbines being used alone at full speed. But still this large addition of cruising turbine has, as we anticipated, not brought down the low speed results to nearly the economy attainable with the reciprocating engine.

No doubt these trials of the Amethyst and Usk are strictly comparable, as they were all carried out by the Admiralty experts, and in all cases only the necessary number of auxiliaries would be kept in service.

The trials of the Usk gave for the coal per indicated horsepower per hour,—

At full speed,	25,372 knots	..................1.79 pounds
At half speed,	13.0 "	..................1.30 pounds

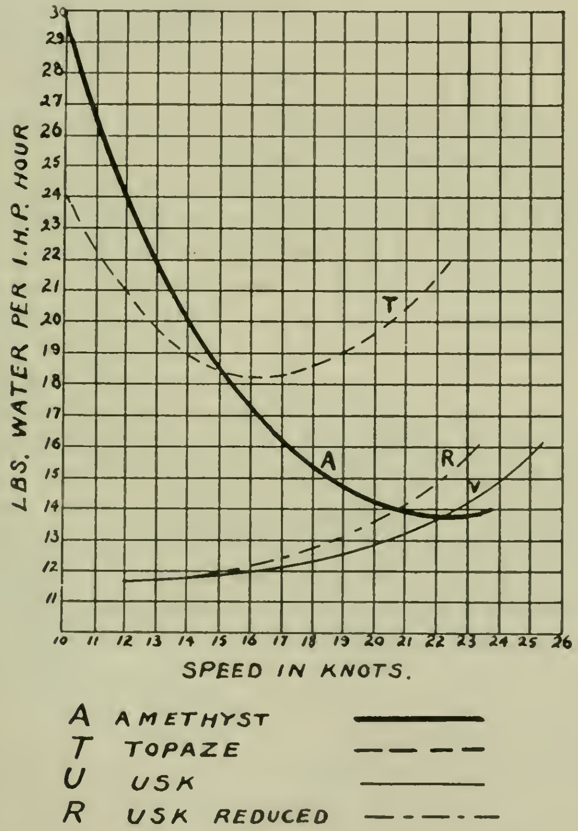
The accompanying diagram is a reproduction of Fig. 4, from the above copy of *Engineering*, page 691, to which we have added a curve U for the Usk. The rates for the Usk's evaporation per pound of coal, which data was not given to us by the Admiralty, are founded on the figures given in *Engineering*, Nov. 18th, for the Amethyst, Topaze and Sapphire.

At full power..............................	8 pounds
At 30 knots...............................	9 pounds

This gives for the Usk,—

At 13.0 knots, 1.30x9=11.7 lbs. water per I.H.P. per hour.
At full power 1.79x8=14.32 lbs. of water per I.H.P. per hour.

Curve U connects the above two values, and was made concave upwards, which is no doubt correct; its exact form we have no data to determine. I have been informed that the low power test of the Usk was with one engine only, but I cannot state this positively. This, of course, is perfectly legitimate. The curve R is the Usk's curve U drawn to a smaller scale of knots, so as to make her full speed the same as the full speed of the Amethyst, 23.63 knots, and thus make a comparison truer,



especially regarding the speed for equal economy shown by the point at which the curves A and R intersect. The intersection occurs between 20 and 21 knots.

The Usk was the most economical of any of the ships for which data was given us by the Admiralty; but, especially at low powers, it is by no means so good as can be obtained with the reciprocating engine. In the Saxonia at what must have been practically full power, as the mean pressures attained show that the H.P. cut off was about .7, the Boiler Committee of the British Admiralty found the following results: (See *Engineering,* Vol. 73, page 278.)

Coal	per	I.H.P.	per	hour		1.29 pounds
Water	"	"	"	"	main engines	13.47 pounds
"	"	"	"	"	auxiliaries	0.86 pounds
"	"	"	"	"	total	14.33 pounds

The results for the Topaze are far from the best which can be obtained by the reciprocating engine.

In making a comparison of any two systems, true conclusions can only be drawn by using the best results which can be attained under working conditions in each case.

The most impressive result shown by trials of the Amethyst and Topaze is, that with the same weight of machinery, the full speed of the Amethyst was fully 1.5 knots above that of her sister ship, and this is greatly to the credit of the turbine. It does not, we think, nearly offset the still large consumption at low powers, as in warships economy and large radius of action at low speed are of such vital importance.

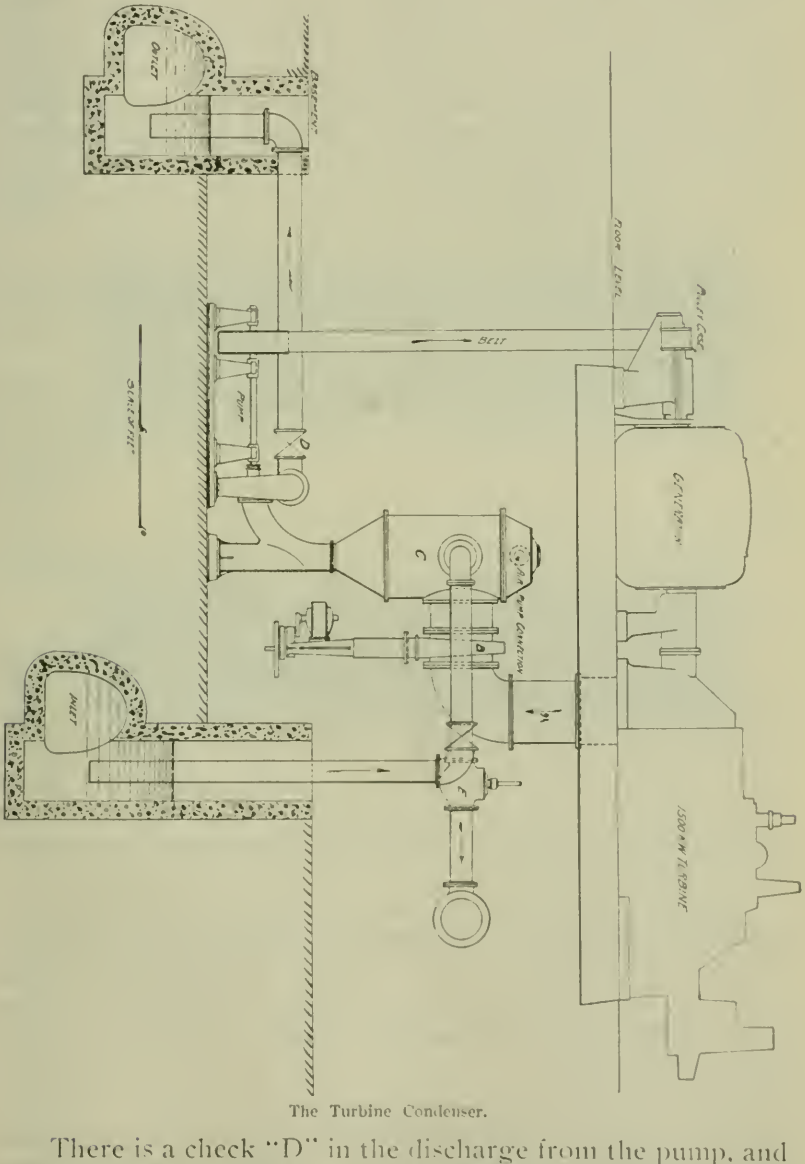
I repeat what we said in our Report, that if the turbine "did prove appreciably more economical even at 20 knots, there is a wide future for it," but we still think its proper application only lies in fine-lined high-speed ships which do not require to cruise much. We would hope that by improvements in design, adding to the rows of blading, or otherwise, the limit of speed for economy equal to that of the reciprocating engine will still be lowered somewhat; as for every fraction of a knot so gained the field for the turbine's application will rapidly broaden.

MR. FRANCIS HEAD gave the following account of the Turbine Condenser, of which a diagramatic view is presented:

The machine in question in a 1500 K.W. turbine of the Parsons type, which was built specially with an extended shaft at the generator end on which a pulley was placed.

The novelty of the scheme is in substituting a centrifugal pump for the usual barometric column.

The exhaust steam is lead through a pipe "A" and a gate valve "B" into the condensing chamber "C"; there, it is condensed by a jet and flows into the opening of a centrifugal pump, which is driven by a belt from the pulley on the extended shaft of the turbine.



The Turbine Condenser.

There is a check "D" in the discharge from the pump, and this discharge is also sealed by the outgoing water. At the top of the condensing chamber is attached the usual dry air pump connection.

The turbine is started as follows:

Valve "B" is closed and the turbine is allowed to exhaust into the atmosphere by the automatic exhaust valve "E"; at the same time the dry air pump produces a vacuum in the chamber which induces a flow of water. When the turbine is up to speed, the pump is going with sufficient velocity to keep the condensing chamber clear, and the valve "B," which for convenience is motor driven, is opened, the free exhaust valve "E" promptly closed and the turbine is running condensing.

In this particular installation the water for condensing is taken from a stream containing a large amount of sewage, and this simple and economical means of handling the problem was therefore adopted.

The plant has only been in operation during the past winter, and from twenty-seven and a-half to twenty-nine inches of vacuum is readily obtained. The first cost of the arrangement is probably less than one-third the cost of a surface-condenser installation, and it requires much less attendance.

It is better than the ordinary barometric column, inasmuch as the condensing chamber is close to the turbine, and there is no loss in vacuum between the turbine and the condenser.

MR. OSCAR C. SCHMIDT.—In the discussion of this evening, nothing has been said which will indicate what the life of a turbine blade will be. This might probably be due to the fact that the life of the turbine industry in this country is comparatively short, but it is claimed by engineers strongly advocating the reciprocating steam engine for central stations, that the defects and faults developed under extended use have not been brought out.

The fact that the steam turbine has been used extensively in Europe, ever since it was introduced in England by Chas. A. Parsons, in 1884, has led us to look to the other side of the Atlantic for much of our data, particularly those facts relating to the wear and tear on turbines which have been in use for some time.

There is no doubt that the steam turbine, when it is new, is an efficient and economical machine, so far as steam consumption is concerned, but what effect has long life upon this economy and efficiency? Nothing up to the present time has been published on this subject. All the tests which have been made in this country or Europe, and which have been published so extensively, have either been made before the turbine left the factory, when it was in the hands of its friends, or shortly after it had been installed. We have no clue as to the cost of maintenance and repairs, and that there is enormous wear upon the back of turbine blades or buckets, on account of wire drawing, or whatever really does take place, in the cylinder of the turbine, is shown by the accompanying illustrations.

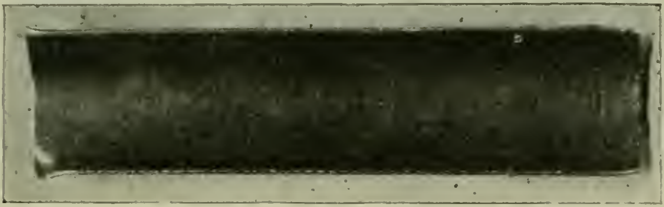


Fig. 1.—Enlarged view of concave side of new Parsons turbine bucket.

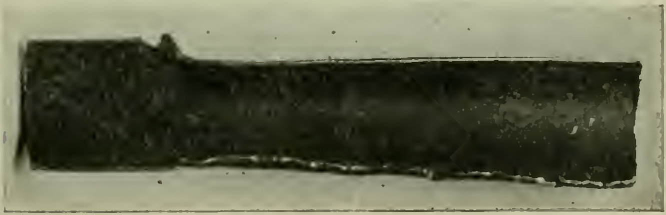


Fig. 2.—Same bucket after having been in use less than one year.

The first illustration represents the front view of a Parsons turbine blade, and Fig. 2 the same blade after it has been in operation less than one year. The third illustration represents the back view of the same bucket before using, and Fig. 4 the same blade after using.

The question I would like to bring up is, "If the turbine blades do wear as much as is represented by the illustrations, what effect will this wear have upon the economy of the turbine?" The wear upon turbine blades is supposed to be reduced by superheating the steam and hence the getting rid of any entrained moisture or condensation is supposed to reduce this wear to a minimum, but this turbine blade was taken from a 300 K.W. turbine which ran with superheated steam at a temperature of about 548° F., the initial steam pressure being 134 pounds per square inch.

As this blade is only one of 31,073 blades which are used in a Parsons turbine of 300 K.W. capacity, and if all the blades are worn after a few years of service to anything like those which are shown, the cost of repairs must necessarily be considerable, and what about the economy in the meantime? Of these 31,073 blades, 16,095 are moving blades and the difference, or 15,978, are stationary or guide vanes.

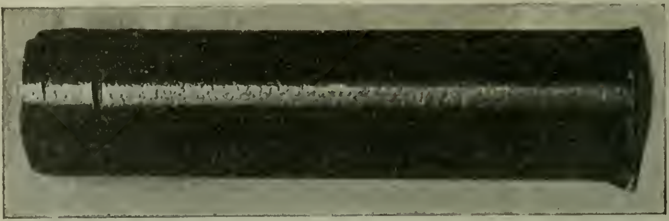


Fig. 3.—Convex side of same bucket when new.

While it has been calculated that there is only a pressure of about one ounce which comes upon each blade as it is revolving, it might be probable that if only a few of these buckets were in the condition shown, the effect upon the economy might not be appreciable.

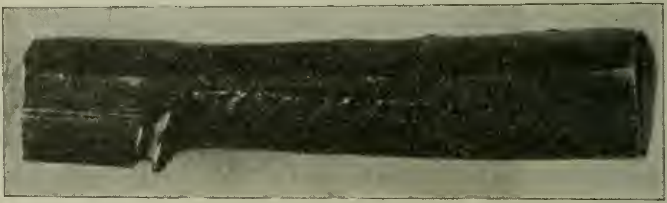


Fig. 4.—Same blade showing wear on convex side.

The fifth illustration represents a De Laval nickel steel bucket, which was in use less than six months, and it is evident that the wear upon one side of the blade was considerable. This blade was taken from a 30 K.W. De Laval turbine, in which there are about 200 buckets.

Fig. 7 represents a De Laval steam turbine cast-steel helical pinion, which was in use less than six months, and Fig. 6 represents a new pinion of the same size and type. The profiles of the teeth in the used pinion are considerably worn away by wear. With the case of the pinion, the cost would be so low that even it it had to be replaced a number of times in a short time, it could hardly be held of great importance against the De Laval turbine.

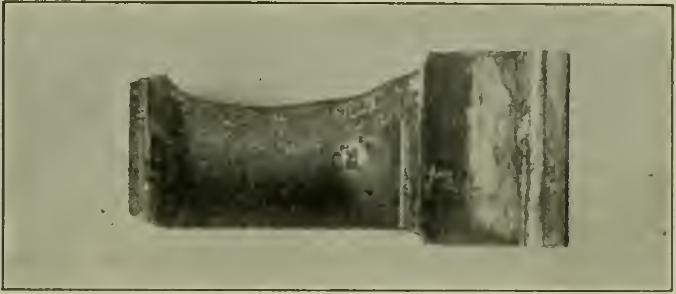


Fig. 5.—Enlarged view of De Laval turbine bucket in use less than six months.

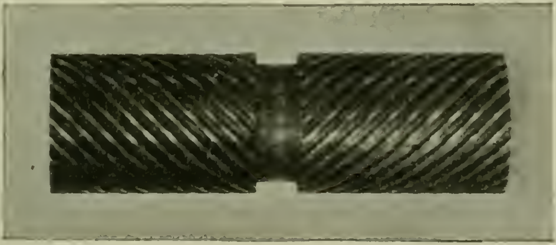


Fig. 6.—De Laval cast-steel pinion.

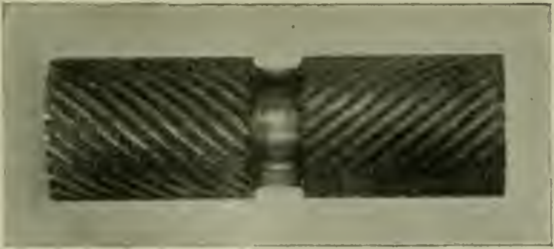


Fig. 7.—Same pinion after having been in use six months.

The question of wear upon the turbine blades of any turbine cannot be so easily dismissed, as the cost of replacing the blades of any of the high power turbines would be quite a serious expense.

It might be stated that the illustrations shown were sent to me by a leading engineer of Europe, who strongly favors the reciprocating steam engine, and whether they apply only to turbines constructed and operated under worst conditions, or are fair examples of the wear and tear on the ordinary steam turbines, cannot be stated, but it seems that from whatever cause turbine blades do wear, and it seems to me that before any owner of a fairly good reciprocating engine replaces it with a turbine on the score of economy, the durability and economy of the turbine after years of service should be fully known.

MR. LAFORE.—In regard to the wear on the De Laval bucket as shown by the view, I believe that such a statement is of little value unaccompanied by exact information as to where the machine was used and some definite information which will establish without question the fact that the bucket was subjected only to normal wear. It has been clearly shown both in practice and by experiments, made by Prof. Spangler and many others, that a steel bucket will not wear materially if subjected to a jet of dry steam. It is, of course, easy to show a worn part of any machine, but I think little importance should be attached to any individual exhibit of this character. As a matter of fact there are not 200 buckets in a 30 H.P. turbine, but only about half this number. There are only 200 buckets in a 300 H.P. turbine. Each of these buckets costs about sixteen to eighteen cents, and are easily replaced. So it can be readily seen that even if a bucket did wear, the expense of replacing it would not be very great. Further, I would state that some buckets with the edges purposely cut away have been tested in turbines and the decrease in economy is very slight, only a few per cent. in fact.

In regard to the photograph showing new pinion, and one having been in use six months, I believe this may indicate little more than a difference in the character of the photographs, and that the same results might have been secured if two photographs had been taken of the same pinion at the same time.

Without regard to this, however, it is self-evident that such exhibits are of little value without absolute knowledge that the pinion was not improperly treated, or subjected to unusual wear. Gears and pinions have been in use in Europe and in the United States for a number of years and have shown no perceptible deterioration, excepting where an accident occurred or some foreign material was allowed to enter the gear case.

Notes and Comments.

THE PANAMA CANAL.

Although it is usually a good proposition to get the best, the principle may not apply with regard to the digging of the Panama Canal. Chief Engineer Wallace strongly favors its construction at sea level, and advances cogent arguments in support of his opinion. He has advised the House Committee on Interstate and Foreign Commerce that a canal so constructed would be less expensive to maintain, less expensive to operate, would save time in passing through it, and could be widened and deepened when required without interfering with traffic. All these are very good reasons, indeed, why a sea level canal should be dug rather than one with a portion of its channel 90 feet higher, requiring the use of locks. But, unfortunately, there are other considerations. Taking as a basis the estimate of the former Canal Committee, that the 90-foot level canal would require ten years for its completion and would cost $200,000,000, he figures that a sea level canal could be opened in fifteen years and completed in twenty years, and would cost $300,000,000. The increased cost will propably not strike the American people as a formidable objection to the adoption of a level which will have so many advantages over one requiring locks, although an extra $100,000,000 is no trifling matter to be lightly considered. The most serious point brought out is the greatly extended time required.

Mr. Wallace bases his estimate on a previous estimate, and both may be much out of the way. Difficulties greater than have thus far been conjectured may develop as the work proceeds, and its completion even at a 90-foot level might be delayed considerably beyond ten years. The attempt to dig a sea level canal might be prolonged far beyond fifteen years until the canal could be opened to vessels of light draft, and it might be twenty-five years until the largest vessels could safely venture through. Those who have been most earnest in their support of the Panama Canal have, of course, been animated either by hopes of a personal benefit or of benefit to existing commercial interests. Surely those who have labored for it in season and out of season were fairly hopeful that if undertaken it would be completed while they were sufficiently interested in mundane affairs to take some cognizance of the fact. But to defer such a hope for twenty or perhaps twenty-five years would mean that very many who are now deeply interested are merely working for the benefit of posterity. If a sea-level canal should be decided upon, it is to be hoped that the estimates of both cost and time are far out of the way, and that both can be heavily reduced. Most especially is it desired that the time can be shortened.—*Iron Age*.

NEW PROCESS OF COLOR PHOTOGRAPHY.

Scientists, dabblers in science and earnest amateur photographers have been trying for years to discover the secret of producing photographic prints in the colors of nature as seen upon the ground glass of the camera and as projected by the lens upon the sensitized plate. The lens views and the plate receives the picture in colors, but the negative plate is incapable of fixing anything else than form and producing that in fine gradations of light and opacity. Color negatives have been made, but have not been capable of transmitting color qualities to positives, nor have color positives been successfully made by any purely photographic principles. Good color effects are produced by superimposing photographic plates in mechanical printing processes, but hitherto there has been little success in chemical reaction upon ordinary printing paper to produce color effects.

Recently, Rudolph Isenmann, of 385 Bergen Street, Newark, N. J., has produced some most promising effects in making color photographs by purely chemical manipulation in the simplest possible manner. With ordinary printing-out paper, either gelatin, albumen or collodion surfaced, such as is sold by photographic stock houses, he claims to make prints containing blue, yellow, green and brown by merely soaking the prints as taken from the printing frames in two successive baths with a washing between the chemical immersions. The colors find their places with wonderful accuracy. The rich cerulean blue arranges itself in the sky with white cloud effect, and in the sunlit parts of the water in the foreground, while the water in the shade of the green trees takes up a greenish cast and the browns and autumnal yellows appear on the leaves and are reflected in the water in some of the pictures. The arrangement of the colors seems to be natural selection influenced entirely by the density of parts in the negatives from which the prints are made. Mr. Isenmann says that he allows the colors to work out their own progress, and never uses any effort to direct them by hand manipulation. He says, further, that the process is extremely simple and cheap. He uses no gold in toning the pictures, nor does he use hyposulphite of soda to fix them. What becomes of the free silver he does not say, but he has samples of his color work which have been made and exposed for six months, and he can see no change in the colors.

While Mr. Isenmann's results are by no means perfect, they show great advance in color photography, and give promise of still greater success. He despairs of ever reaching the reds by this process, but feels that he has secured a satisfactory end by extremely simple means.—*Scientific American Supplement.*

IRON AND IRON SUPPLIES.

Pennsylvania, which makes more than half the iron used in the United States, produces less than 2 per cent. of the iron ore mined. Ohio, which comes next to Pennsylvania as an iron-maker, mines less than 0.1 per cent. of the total. In both cases the ore is brought to the fuel; and this is the policy in this country. Only in Alabama are the ore and fuel found together.

WILLIAM SELLERS,
1824–1905.
President Franklin Institute, 1864–1867.

THE FRANKLIN INSTITUTE

William Sellers.

When a man of pre-eminent abilities and world-wide fame as an engineer and manufacturer, whose life was spent in activities contributing to the advancement of knowledge in his chosen profession, passes away at a ripe old age—having retained to the last an active interest in his business and in public affairs—it is proper that a permanent record of his useful life should be made available for the benefit, not merely of his friends and contemporaries, but of future generations as well.

Such a man in all respects was William Sellers, the former President of the Franklin Institute, to whose solicitude was due, in large measure, the preservation of the Institute at a critical period of its history and its subsequent advancement. It is eminently fitting, therefore, that a suitable tribute, in the form of a biographical notice, should appear in these pages in conformity with the resolution of the Board of Managers.

Mr. Sellers was born in Upper Darby, Delaware county, Pa., September 19, 1824; son of John and Elizabeth Sellers, grandson of John and Mary Sellers and of William and Sarah Poole, and a descendant of Samuel Sellers, who, with his brother, George, from Belper, Derbyshire, England, emigrated to this country and arrived in Philadelphia in 1682. George died unmarried. The marriage of Samuel Sellers and Anna Gibbons is the first recorded in Darby meeting of Friends. He took up a tract of land in Upper Darby, Delaware county, under Penn's Patent. This property has remained in possession of his descendants to the present generation, and on a portion of it is the house in which the parents of William Sellers resided when he was born. His ancestors have had a long and memorable connection with science. From the organization of the American Philosophical Society some one of his family has always been a member of it. His paternal grandfather, John Sellers, then a member of Assembly of Pennsylvania, was appointed by this society in connection with three other members, to observe the transit of Venus in 1761, and his maternal grandfather, William Poole, came from England to observe the same transit and remained here.

William Sellers was educated at a private school, built and maintained by his father and two relatives for the education of their children.He was apprenticed to the machinist's trade with his uncle, John Morton Poole, of Wilmington, Del., for nearly seven years.

After he was twenty-one years of age, in 1845, he took charge of the large machine shop of Fairbanks, Bancroft & Co., in Providence, R. I. In 1848, he commenced the manufacture of machinists' tools and mill gearing, at 30th and Chestnut streets, Philadelphia, and subsequently joined Edward Bancroft, who, in the meantime, had removed from Providence, R. I., to Beach street, Kensington. The new firm was Bancroft & Sellers. Later John Sellers, Jr., was admitted as a partner, and in 1853 the new shop at 16th and Pennsylvania Avenue was ready for occupancy, and the firm removed to that site. Mr. Bancroft died about 1856, and the firm became William Sellers & Co. In 1886 the corporation of William Sellers & Co., Incorporated, was established, with William Sellers as President.

In 1868 he formed the Edgmoor Iron Co., of which he was the President. This company furnished all the iron structural material for the Centennial Exhibition buildings, and also furnished all the structural material used in the Brooklyn Bridge, which they built, with the exception of the suspension cables, supplied by the Roeblings. This bridge was the first in which steel eye-bars were used. At that time the Edgmoor was the largest plant in the world for building bridges and other structures of iron and steel.

In 1873 Mr. Sellers became President of the Midvale Steel Co., Nicetown, Phila., which he subsequently reorganized, and under his management became the first successful producer of material required by the Government for its steel cannon.

The development of the business of the Edgmoor Iron Co. turned the inventive ability of Mr. Sellers in new directions, and a long series of mechanical devices was evolved to meet the changing requirements of that business. The works were first started to make wrought-iron by mechanical puddling machinery of a new type, were subsequently changed to a bridge shop, and later a department was created for the manufacture of boilers of various kinds. Each step in this growth called for new machinery and new methods, and throughout the development Mr. Sellers' personality dominated at every step. He was ever ready with suggestions for improvement in plant and in appliances, and he developed many original devices. Some of this machinery followed along accepted lines, but much was original in conception and design. Among the more striking features may be mentioned a comprehensive hydraulic plant for making upset rods and eye bars,—the latter were first made of iron by a welding process and then of steel by upsetting and and flattening, and involved the use of a special and original annealing furnace for very long bars. Again, there were multiple punches and spacing mechanism for rapidly producing plate girder work without templates, hydraulic riveters, cranes, drills, boring machines and many other devices for the rapid and effective production of work. Each step developed new requirements, and each found him ready with suggestions.

Mr. Sellers was not only a maker of machinery. He was a judge of men and moulder of character, and it is worthy of note that in each of the great establishments which he dominated he gathered about him a staff of efficient and loyal subordinates, who earnestly strove to carry out his wishes. His rule was just, but strict and firm, and it developed industry, system, earnestness, order and thoroughness.

It has been our purpose in gathering material for a biographical notice of the career of William Sellers for the pages of this journal, to dwell especially upon his achievements in the immediate line of his profession as an engineer and a successful manufacturer, but apart from these activities Mr. Sellers' interests were varied and his influence on public affairs was extensive. The Pennsylvania limited liability corporation law was enacted largely because of his efforts, and as one of the two vice-presidents of the Board of Finance of the Centennial Exhibition he devoted so much attention to his duties that it has been said of him that "the success of the Exhibition was largely due to his personal efforts."

In his capacity of Trustee of the University of Pennsylvania he served continuously for no less than thirty-seven years. At the stated meeting of the Board of Trustees, held on February 7th, 1905, the following minute was unanimously adopted and ordered to be spread upon the minutes:

"The Trustees having learned with the deepest sorrow of the death of their late colleague,

WILLIAM SELLERS,

senior member of the Board, hereby record their sense of the loss sustained by them and the University.

"Mr. Sellers entered the Board in 1868, and during his thirty-seven years of continuous and active service the University has become one of the foremost institutions of learning in America. In all these years his interest has been unfailing and his place will be difficult to fill, especially in the place of the engineering schools, to the organization and development of which his knowledge and experience were so valuable.

"In expressing their personal loss, the Trustees offer their respectful sympathy to Mrs. Sellers and other members of his family."

At the outbreak of the Civil War, Mr. Sellers took an active part in organizing public opinion and in enlisting troops for the Union cause. He was one of the original charter members of the Union Club, formed by a few of the leading patriotic citizens of Philadelphia, out of which afterwards grew the Union League.

In 1864 he was elected a member of the Philosophical Society, and in 1873 became a member of the Academy of Natural Sciences, serving for many years on the Finance Committee; he was a member of the Institute of Mechanical Engineers; he was a Commissioner of Fairmount Park from 1867 to 1872; he was a member of the Institute of Mechanical Engineers of Great Britain, the Iron and Steel Institute of Great Britain, a corresponding member of the Société d'encouragement pour L'Industrie Nationale, in Paris, and at the close of the Paris Exposition, in 1889, the decoration of Chevalier de la Legion d'Honneur was conferred upon him. In addition to the foregoing, he was a member of the American Society of Civil Engineers, the American Society of Mechanical Engineers, the

Philadelphia Contributionship and numerous other associations.

As a designer of machinery, William Sellers had certain well defined ideas. Beauty of line and grace of form were insisted on, and he early adopted, if he did not invent, the dull lead tint now known as "machine gray," which has now almost entirely supplanted the reds and greens and blacks of the early builders. Fitness for the purpose intended, as he saw it, was the keynote, and he had as much horror of unnecessary weight as he had of any other defect in proportion. In construction nothing suited him but the best. He was never deterred by consideration of cost if he saw a way of improving in design or construction. Absolute honesty of purpose was his dominant characteristic, and he would tolerate no deviation from the standard of workmanship, no matter how tempting might be the occasion. There was no thought of patching defects in workmanship or material. Nothing was "good enough" unless it was perfect.* Jealous of his reputation, he set a high standard and followed it undeviatingly. He had to a wonderful degree the courage of conviction and would follow out his own conclusions without hesitation in the face of adverse opinion. In fact, opinions had very little weight with him in professional matters, but he would always listen to reasons, and if the reasons appealed to him he would abandon preconceived convictions readily and without apparent regret. He used to say that he had no "pride of invention," and would readily give up an idea on which he had long labored if convinced that something else offered was better.

As illustrating William Sellers' mechanical ingenuity and fertility of resources it may be noted that he was granted about ninety U. S. patents, either alone or in conjunction with others, the earliest was granted in 1857; and that he had patents pending when he died. These numerous patents granted to him alone, or in association with co-inventors, cover a great variety of subjects—machine tools, injectors, rifling machine, riveters, boilers, hydraulic machinery of various sorts, furnaces, hoists, cranes, steam hammers, steam engines, ordnance, turntables, pumps, &c. He also obtained many patents in foreign lands. Probably the best known of his inventions is the spiral-gear planer drive, in which the table or platen is moved back and forth by a multi-thread screw on an inclined shaft engaging with a rack on the under surface of the table—a device giving the smoothness of a screw drive coupled with the convenience and efficiency of the usual spur-gear arrangement while permitting a stronger bed framing. This entirely new device proved from the first a great improvement over existing methods, and remains to this day unexcelled. It was patented in 1862.

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*On one occasion while conducting a friend, who was also engaged in the iron business, through the works, the latter commented on the absence of any bad castings, and asked what method was adopted to prevent their occurrence. "We throw them away," was the reply.

Mr. Frederick A. Halsey has aptly defined the late William Sellers' status as an engineer in the following words:

"Mr. Sellers has been called the Whitworth of America, the work of the two men being largely on parallel lines and their influence in England and the United States being substantially the same. The merit of Mr. Sellers' work is scarcely less than that of Mr. (Sir Joseph) Whitworth, and when considered in connection with the greater difficulties to be met, it is perhaps even greater. The machine building industry in this country was then in a far more primitive condition than in England; the soil of the country was much less receptive of those advanced ideas which form the foundation of Mr. Sellers' work. His work was from the beginning strikingly original, so much so that to those whose ideas were based upon the undeveloped taste of that time they seemed in many cases almost outre. The writer recently saw, still in use, one of the early special lathes designed by Mr. Sellers for turning railway axles, and so entirely different was it from any form of lathe made at that time that it could scarcely have failed to impress the general observer as a simple oddity. As a matter of fact, it was obviously the result of the keenest analysis of the work to be done and of the strains to be carried by the machine, and the result was simply an adaptation of the form of the machine to these strains—little less than a stroke of genius. While, of course, these machines have been improved and made capable of a much larger output than this early machine of Mr. Sellers', it is nevertheless not exaggerating to say that its outlines form to-day a model.

"It was this adaptation of the forms of his machine to the strains to be carried by them that formed the keynote of Mr. Sellers' method of design, and it was the fact that machines were then designed regardless of such principles that led his forms to appear so strange to those who looked upon the prevailing forms as suitable. Mr. Sellers' methods, however, were soon followed by other designers, and it is safe to say that, so far as modern machines are better in this respect than those of half a century ago, the result is very largely due to the influence of Mr. Sellers' work. This influence is seen more and more in connection with the most recent designs of machines. The influence of tradition is far stronger in connection with these machines (which in a sense became standard many years ago), than those of recent origin, and it is therefore a curious fact that the most modern outlines are seen in machines upon which the opportunity for improvement has prevailed the longest.

"Of his individual achievements Mr. Sellers' name is best known in connection with the Sellers or United States Standard Screw-thread, which he published in a paper read before the Franklin Institute in 1864, at which time he was President of the Institute. A similar effort towards standardization had been previously made by Sir Joseph Whitworth, and Mr. Sellers' work was no doubt inspired by that of Whitworth. The leading differences between the Sellers and Whitworth forms lie in the angle of the thread and in the fact that it has a flat top and bottom instead of a round top and bottom. There has been much discussion regarding the merits of these two forms, of which both have their advantages, but it is safe to say that from the strictly practical standpoint (of getting the standard generally adopted) the Sellers form is the only one which would have had any chance of general adoption in this country at that time. It had the commanding merit that it could be made with a common lathe tool, made in the shop where used, whereas the Whitworth form required a special tool which must be bought from a maker. In addition to the smaller tendency to respect and follow authority in this country as compared with England lay the physical obstacle due to the widely scattered mechanical centers of the country, the effect of which could only have been to defeat standardization should the proposed standard involve the purchase of special tools for thread cutting. How much of an influence this may have had with Mr. Sellers the writer does not know, but it may well have had a commanding influence."

It has been truly said of William Sellers that he had "the courage of his convictions," and this prominent trait of his character is illustrated in the following incident:

In 1890, the Navy Department of the United States Government, at Washington, sent to leading manufacturers of machine tools elaborate specifications for an eight-foot turning and boring lathe for sixteen-inch steel cannon. This was a leviathan lathe; some idea of its dimensions may be gained when it is stated that the main bed was 73 feet 10¾ inches long and 9 feet wide, the extension bed for carrying the boring arrangement was 53 feet 5 inches long, and 5 feet 2 inches wide, making a total length of 128 feet 3¾ inches.

The Government engineers designed this gigantic machine. Mr. Sellers did not approve of their designs and refused to bid upon them; but he caused new designs to be drawn embodying new principles, differing radically from the Government's drawings. On a day appointed, Mr. Sellers appeared in person and explained his design to the Board of Engineers in Washington, pointing out the merits of his plans, and so thoroughly convinced the Board of their superiority that they adopted the Sellers' plans and discarded their own. This great lathe was built by William Sellers & Co., Incorp., and installed in the Naval Gun Factory in Washington, D. C., where it has attracted the attention and admiration of engineers from all parts of the world. The total weight of this machine was about 500,000 pounds.

During a visit to England, in 1860, the attention of Mr. Sellers was called by Sharp, Stewart & Co., of Manchester, to the Giffard Injector for feeding steam boilers, a model of which had been sent by Flaud et Cie., of Paris, for the purpose of interesting English manufacturers.The device was crude in design, and was generally regarded as a mechanical paradox and an interesting but unpractical toy; it contained, however, the elements of a novel principle, and Mr. Sellers' immediate estimate of the value of the invention evinces the accuracy of his judgment. American rights were at once obtained and royalties paid to Sharp, Stewart & Co., until the expiration of the United States patents.

The same year a special department devoted to the manufacture was added to the plant of William Sellers & Co., and the first injectors were made from French drawings and patterns. Modifications of the original design were introduced to adapt it to the American market, and the present experimental department established to eradicate defects of construction and to obtain a more complete development of the principle. The necessity for automatic adjustment was soon observed, and Mr. Sellers invented and patented, in 1865, the self-adjusting combining tube, which automatically adjusted the supply of water to meet the requirements of varying steam pressures, and improved forms bearing patent dates of 1876 and 1878 are still largely used. Other interests diverted the trend of Mr. Sellers' inventive ability into other channels, and in his later years further experimental work was placed in the hands of Mr. Strickland L. Kneass, but he always retained his deep interest in the subject. In 1888, the self-acting form, devised and patented by Mr. Kneass, was introduced, specially adapted to the high boiler pressure carried on locomotive boilers, and met with immediate acceptance, being adopted by most of the railways of France as the standard, so that injectors bearing William Sellers' name supplanted Giffard's in the country of the inventor, besides being used in almost every country and colony of the globe. In fact, it may be added, that his name is as closely associated with the highest development of the locomotive injector as it has been with the perfection of machine tools or the standard screw thread.

Mr. S. M. Vauclain, Superintendent of the Baldwin Locomotive Works, sends us, as this goes to print, the following appreciative letter:

"It is impossible for me to put in writing exactly my estimation of the late William Sellers. To me he always has been the acme of eminence in the machine tool section of mechanical engineering.

"His productions were always the very best of their respective kind, and as he once very quietly remarked, 'One might object to the price, but never would to the machine.'

"An acquaintance of over twenty years brought him very near to me—the wisdom of his counsel, the excellence of his judgment and his absolute honesty in all things placed him upon a pedestal far above others in our profession.

"At the time of his death I regarded him as the Grand Old Man of Philadelphia, and the father of the great machine tool industry of the world, and surely no man has as yet done so much to promote the art, or establish fixed principles therein from which it would be suicidal to depart.

"You must bear with me when I tell you how impossible it is to express my appreciation of him as a mechanic, engineer, citizen and friend—when we have the ideal, we find that words are unable to describe. Such a man was William Sellers; his name will ever remain green with those who were his friends, and so fortunate as to have been his nearest neighbors.

"Yours truly,

"S. M. Vauclain."

Mr. Wilfred Lewis, M.E., offers the following note:

"It was my privilege for over twenty years to be closely in touch with the engineering enterprises of the late William Sellers, and having contributed perhaps as much as anybody to the scrap-heap out of which his genius drew forth many fruitful results, I can speak of the man and his work from intimate personal knowledge.

"He was an indefatigable worker, and concentrated all his energies upon the problem in hand, whatever it might be, going into the minutest details, while at the same time he never lost sight of the main object in view nor of the completed mechanism or structure as an harmonious whole. An artistic sense of proportion was always present in his mind, but the foundation for his idea of beauty was fitness. When a thing was right he knew it would look right, and he always sought the most direct means to an end as his ideal of mechanical perfection. Endowed with a fertile imagination and strong common sense, he made many useful inventions, and few if any of the sort whose chief merit lies in the ingenuity displayed. It has been truly said that he had no pride of invention, for he was always ready to accept the suggestions of others and put aside his own ideas when it seemed wiser to discard them. What he stood for was the best to be gathered from any source, and his own contribution to a successful issue was as often in the shape of well directed criticism as in that of actual invention. He was quick to appreciate a good suggestion and as quick to condemn a bad one, and I think everyone who worked for Mr. Sellers felt inspired to do his best by the knowledge that his efforts would stand or fall on their own merits in the eyes of an impartial critic. He was patient, tolerant and kind to honest effort along the lines laid down by him for development, but as inflexible as steel to any departure from those lines until he was satisfied of their futility.

"He knew how to give an order and exact obedience, and only to those who showed the capacity to obey did he extend the authority to direct the management of his affairs, while over all he never failed to exercise a masterly control.

"Of commanding presence and stern appearance, he was nevertheless approachable on any subject and always ready to render a decision upon any question that might arise. When in doubt everyone knew where to turn for guidance, and with apparently little effort this captain of industry kept his forces busy within clearly defined lines. His decision of character was one of the strongest elements in his success, and a purpose once formed was carried through to its logical conclusion regardless of obstacles, the sweeping away of which seemed to be a delight.

"In many directions he was a pioneer inventor, and the high standard of machine construction in America may be said to have been set by William Sellers. The best that could be achieved was never too good for him, and no expense was spared to keep ahead of all competitors in design and construction. This supreme excellence may have opened the door to successful competition, but it emphasizes rather than detracts from the recognized position of William Sellers as the greatest tool builder of his day and generation.

"WILFRED LEWIS."

Mr. Strickland L. Kneass, C.E., contributes the following interesting account of some experiments made at the Naval Gun Factory, in Washington, D. C., carrying out to a successful conclusion William Sellers' new projects involving radical changes in construction of "built up" steel cannon and the method of assembling and dis-assembling the various parts:

"While designing and manufacturing the large lathes and boring machines for the Naval Gun Factory, Mr. Sellers also became interested in the problem of gun construction. He carefully analyzed existing methods and determined upon a bold and simple design, reducing the number of parts and increasing the longitudinal strength and accuracy during fire. He contemplated substituting for the breech and chase rings one continuous inner jacket and a superimposed outer jacket, reducing the essential parts from thirteen to three.

"With existing apparatus, this was impossible, and Mr. Sellers designed and built an assembling furnace for an 8″ Breech Loading Rifle, the tube and jackets of which were made at Washington. He placed the experimental work in the hands of the writer, and in 1891 tests were made with models upon a scale of 1-12, which showed conclusively that jackets could not only be shrunk in place, but could also be removed by Mr. Sellers' method, indicating the possibility of dis-assembling a gun and replacing a tube eroded by powder action. The scheme was brilliant, but required new and specially-designed heating furnaces, rapid cooling stands and pyrometers for determining the internal temperature of the tube and jackets at various points. Each part of the problem was attacked in an original and ingenious manner, and his complete apparatus was used by the writer at the Naval Gun Factory, at Washington, during the summer of 1894. As was to be expected with a problem involving such difficulties, further experimental work was required, but on August 1st, 1904, the inner jacket 21 ft. 9″ was dropped over the steel gun tube 25 ft. 4″ long and shrunk to place. The parts of the gun were then removed from the furnace, and after cooling to normal temperature were again placed in the heating furnace, and the same operation was accomplished with the outer jacket.

"After an interval of nearly two years, in January, 1897, the dis-assembling was attempted; it was not surprising that with an operation of such paramount difficulty, the weight of the gun being 31,975 pounds, and that of the furnace 35,000 pounds, further experimental work was required, especially as most of the practical men connected with the Gun Factory declared the feat to be impossible. The total area of contact of the inner jacket and tube was 85 sq. ft., and the bore before assembling was 0.019″ smaller than the diameter of the tube, exerting a contact pressure when shrunk to place of about 50,000 pounds per sq. in. After several trials, in February, 1897, the tube was successfully removed from the inner jacket, and in the following month the outer jacket was taken off, justifying Mr. Sellers' faith in his scheme and rendering possible the construction and dis-assembling of large breech loading rifles at considerable saving to the Government."

STRICKLAND L. KNEASS.

The Secretary of the Franklin Institute says:

"Mr. Sellers' relations with the Franklin Institute began with his election as a member, in 1847, and continued uninterruptedly until his death. He served as a member of the Board of Managers from 1857 to 1861, and again from 1864 to 1892, inclusive. His services during a period of severe financial stress from which the Institute suffered in the early sixties, as the consequence of an unfortunate investment of its funds, will ever be held in grateful remembrance.

"It was largely due to the personal efforts of a special committee, of which he was a member, that a considerable sum was subscribed to free the Institute from its most pressing obligations, to which fund he was likewise a liberal contributor.

"After the reorganization of the Institute, in 1864, under an amended charter, in which movement he was an active participant, he became the first President of the reorganized body, serving in this office from 1864 to 1867, and his administration of its affairs was signalized by notable increase in its activity. Perhaps the most prominent incident of his administration was the formulation, by a special committee, of which he was the chairman, of a uniform system of screw threads, which was presented in the form of a report read at the stated meeting of the Institute, held September 15, 1864 (see the *Journal*, January, 1865). This report, with its suggestions, was approved by the Institute, and within a comparatively few years, the system of screw threads proposed therein, was officially adopted by the United States Government in its workshops, by the leading railroad companies, prominent machine tool builders and others under the various names of United States, Sellers or Franklin Institute system. It is now in universal use throughout the country."

Other attempts had been made to standardize threads for screws, but William Sellers was the first to devise a set of proportions and reduce them to formulæ so that the proper size, shape and pitch for a given diameter of screw can be determined without comparison with a pre-determined list. The angle and the truncated form of screw thread proposed by Mr. Sellers, which became the standard for the United States, were adopted by the International Congress for "L' Unification Des Filetages et des Gauges," held at Zurich, in October, 1901.

In reviewing the life and attainments of William Sellers, it is proper to allude to the numerous awards given at various international expositions to the house of which he was the senior, and after incorporation the President, as well as to the honors conferred upon him as an individual in recognition of his genius as an inventor and constructor of machinery.

At Vienna, in 1873, in addition to five bronze medals, there was awarded the GRAND MEDAL OF HONOR upon the following recommendation of the jury, viz.: "SELLERS. For pre-eminent achievements in the invention and construction of machine tools, many of which have been adopted as patterns by the constructors of tools in all countries." This diploma was awarded exclusively by the Council of Presidents and was, as therein stated: "Designed to bear the character of peculiar distinction for eminent merits in the domain of science and its application to the education of the people, and the advancement of the intellectual, moral and material welfare of man."

The following extract from the report of the judges appointed for the examination of Group XXI (machine tools) at the Centennial Exhibition will suffice to indicate the nature of the award given to William Sellers & Co. for their exhibits.

"The undersigned, having examined the products herein described, respectfully recommend the same to the United States Centennial Commission for award for the following reasons, viz.:

"For a remarkable collection of machine tools for working metal. This exhibit, when considered in regard to its extent and value, its extraordinary variety and general excellence, as also for the large amount of originality that is shown in the numerous devices that are introduced, is probably without a parallel in the past history of international exhibitions, and, taken as a whole is worthy of the highest honor that can be conferred. Besides, it is thoroughly national in its characteristics and pre-eminently worthy of the United States and of the grand occasion of the Centennial Exposition. Every single machine, tool or piece of apparatus that is displayed in this vast offering, would, for itself, command the strongest recommendation for an award, even if it stood alone as a unit; but here every unit is surrounded by thirty-three distinct machines, each one being of the highest standard in its particular class. The whole of these machines are characterized by extreme refinement in detail; by the superior quality of the material employed in their construction; by first-class workmanship, both in regard to nice fitting and precision, and for the mathematical accuracy of all the parts; by the beautiful outlines that are imparted to each structure; by the correct proportions that have been worked out in the determining of strength and form; and the disposal of material to take its full share of duty. For the scientific skill displayed in the application of mechanical force, for the daring shown in fearlesly breaking though the trammels of the past by introducing variously constructed devices and arrangements of gearing for the transmission of power in more direct course to the point of action, yet maintaining correct construction mechanically, and without departure from true principles. As it is impossible to realize the full measure of such refined mechanical, scientific and artistic merit, by the foregoing remarks, it is deemed necessary to enumerate briefly some of the more prominent points in the several machines, both in justice to the exhibitor and to the judges."

Here followed a description of twenty-two distinct exhibits.

Remarkable as was the foregoing tribute to an American exhibit of machine tools, it was still more gratifying from the fact the jury was composed of men of various nations having international reputations, as the following list of names will show:

John Anderson, LL.D., C.E., etc., Woolwich Arsenal, Great Britain.
Prof. C. A. Angstrom........................Sweden.

August Gobert, Jr.	Belgium.
F. Reifer	Austria.
M. Le Commandant F. Perrier	France.
George H. Blelock	Springfield, Mass.
N. F. Durfee	New York.
Professor J. A. Anderson	Manhattan, Kansas.

Dr. John Anderson (Mechanical head of Woolwich Arsenal) was the chairman of this group.

To give detailed accounts of all the awards made in past years to William Sellers & Co. at the various national and international expositions would necessarily extend this article beyond the prescribed limits. The following list must therefore suffice without further comment thereon:

AWARDS TO WILLIAM SELLERS & CO., INCORP.

1854—Franklin Institute, Philadelphia, Silver Medal.
1857—Maryland Institute, Baltimore, Silver Medal.
1867—World's Fair, Paris, Gold Medal.
1869—American Institute, New York, Six Medals.
1873—World's Fair, Vienna, Five Medals and Grand Diploma of Honor.
1876—Centennial Exhibition, Five Medals and Report of International Jury.
1880—Imperial Technological Society, St. Petersburg, One Medal.
1883—Exhibition of Railway Appliances, Chicago, One Gold Medal, Four Silver Medals.
1889—World's Fair, Paris, Grand Prize.
1904—Louisiana Purchase Exposition, St. Louis, Grand Prize and Gold Medal.

Note.—William Sellers & Co., Incorp., have made no competitive display at any exhibition other than those mentioned above.

At the conclusion of the Louisiana Purchase Exposition, Mr. Sellers was informed by letter from the chief of the Department of Machinery that he had been awarded a "Grand prize as collaborateur in recognition of your (his) genius as a pioneer in the development in America of Machine Tools of the highest class." This grand prize is a distinction awarded to a few of the most distinguished men of science, and is quite distinct from the awards given for exhibits at the exposition. Since the death of Mr. Sellers an official card of announcement of this award granted by the International Jury of Awards, has been received from the Secretary of Awards.

Mr. Sellers was a man of iron constitution and commanding presence, his words were direct and forcible and his manner was gracious. His opinions and counsel were sought in times of difficulty by men in all walks of life, and his judgment was regarded as of the greatest value, not only in engineering matters, but in civic and governmental affairs of importance. He never sought nor accepted public office.

Soon after the visit of the Iron and Steel Institute of Great Britain to Philadelphia, in 1904, Mr. Sellers received the following letter:

"We, the President, Council and members of the Iron and Steel Institute, desire to convey to William Sellers our sincere and cordial thanks for the very great personal services assiduously rendered with such exceeding kindness and marked courtesy to the members of the Institute during their visit to the United States of America, in 1904."

Signed by the President, Andrew Carnegie, and others.

Several years ago the late Sir Joseph Whitworth said of William Sellers in conversation, that he was "the greatest mechanical engineer in the world." This was a high tribute, indeed, for Sir Joseph Whitworth was, himself, one of the leading mechanical engineers in the world.

Mr. Sellers died January 24, 1905, in the 81st year of his age.

ALEXANDER E. OUTERBRIDGE, JR., } Committee.
COLEMAN SELLERS, JR., }

AMBER.

The Prussian Government collects over $380,000 annually as revenue from the amber mines of Palmicken. From 1803 to 1811 the industry had to receive a subsidy from the Government; now it is self-supporting. In the twenty years from 1883 to 1902 the Palmicken mines produced 8,458 metric tons of amber, the record being established in the last three years.

The value of amber used in America last year was $210,709, making it the second largest consumer in the world. Besides smoking materials, ornamental beads and other articles are made from imported amber.

RAMSAY ON RADIUM.

In *Harper's Magazine* for December, Sir William Ramsay, the discoverer of helium, writes of 'Radium and its products." The results of Ramsay's work have been almost a justification of the idea of alchemy—the transmutation of one metal into another:

"The chemical examination of the products of change of radium leads to a hypothesis as regards the constitution of radium and similar elements, which was first put forward by Rutherford and Soddy. It is that atoms of elements of high atomic weight, such as radium, uranium, thorium and the suspected elements—polonium and actinium—are unstable; that they undergo spontaneous change into other forms of matter, themselves radioactive, and themselves unstable; and that, finally, elements are produced which, on account of their non-radioactivity, are as a rule impossible to recognize, for their minute amount precludes the application of any ordinary test with success. The recognition of helium, however, which is comparatively easy of detection, lends great support to this hypothesis.

"The natural question which suggests itself is: Are other elements undergoing similar changes? Can it be that their rate of change is so slow that it cannot be detected? Prof. J. J. Thomson has attempted to answer this question, and he has found that many ordinary elements are faintly radioactive; but the answer is still incomplete, for, first, radium is so enormously radioactive that the merest trace of one of its salts in the salt of another element would produce such radioactivity; and, second, it is not proved that radioactivity is an invariable accompaniment of such change: or, again, it may be evolved so slowly as to escape detection. A lump of coal, for example, is slowly being oxidized by the oxygen of the air; oxidation is attended by a rise of temperature, but the most delicate thermometer would detect no difference between the temperature of a lump of coal and that of the surrounding air, for the rate of oxidation is so slow."

SUBWAY ENGINEERING IN 1904.

Probably the most important event in the world of civil engineering during the year was the opening of the Rapid Transit Subway in New York. While this is not by any means the first subway built to accommodate the passenger traffic of a large city, it is certainly the first attempt to provide a genuine express service over a four-track tunnel road. The system has been in operation long enough to prove that it is possible to run an underground service of fast trains under short headway with a minimum of risk and a maximum of punctuality and general comfort—all below the surface of the ground and entirely independent of street traffic. The past year has seen the opening of the unique system of freight subway, which has been built below the business portion of the city of Chicago. It includes a series of trunk lines running beneath the principal streets, with feeder lines extending below the cross streets, whereby freight may be taken from the terminal stations of the great roads that center in Chicago direct to the shipping floors of the various business houses. Twenty miles out of the sixty miles of tunnels contemplated by this scheme have been completed.—*Scientific American.*

CHEMICAL SECTION

Stated Meeting, held Thursday, March 12, 1904.

On the Distribution of Velocity Among the Members of a Group of Gas Molecules.

By G. H. Meeker, M.S., Ph.D.,

Professor of Chemistry, Medico-Chirurgical College, Philadelphia.

[Abstract:—This paper is an investigation of a problem in the kinetic theory of gases. Six arguments are given—all leading to the same conclusion: viz., That in a group of gas molecules of equal mass, in a steady state, at constant temperature, the molecular velocities are sensibly equal; and do not vary from zero to infinity, as is generally assumed by writers in the field of the kinetic theory of gases.—The Editor.]

Statement of the Propositions.—While many eminent investigators have given us the results of their mathematical researches in the field of the kinetic theory of gases, it would appear, from what is to be said below, that they have too lightly considered the question of the distribution of velocities among the members of a group of gas molecules, while the gas remains at constant temperature. It seems to have been quite universally assumed as a starting point that, given a gas at constant temperature and composed of a congeries of molecules of equal mass, then (while the velocities in the group of molecules preserve a certain average value—*i. e.*, the square root of the average of the squares of all the velocities—named by Maxwell, the velocity of mean square) the individual molecules have very varying velocities. Thus, Maxwell (Enc. Brit., 9th Ed., III, 40) says that whereas Clausius in his earlier work had assumed the molecular velocities to be equal, Maxwell has shown that the velocities vary from 0 to ∞. Maxwell says also (Theory of Heat, 10th Ed., 315, 316, 338) "Let us suppose a number of molecules in motion—the first thing we notice about this moving system is that even if all the molecules have the same velocity originally, their encounters will produce an inequality of velocity. It appears then that of the molecules composing the system some are moving very slowly, a few are moving with enormous velocities, and the greater number with intermediate velocities . . . Let us suppose a vessel . . . full of air at constant temperature . . . divided into two portions, A and B, by a division in which there is a small hole, and that a being who can see the individual molecules, opens and closes this hole so as to allow only the swifter molecules to pass from A to B, and only the slower ones to pass from B to A. He will thus, without expenditure of work, raise the temperature of B and lower that of A, in contradiction to the second law of Thermodynamics." "Maxwell's demons" (as the above beings are commonly designated) have become famous.

These statements from Maxwell's works serve to outline the prevalent ideas of the day as to the distribution of molecular velocities among the members of a group of like molecules in a gas at constant temperature.

It is the purpose of this paper to call attention to certain reasons for thinking that the opinions just sketched are erroneous. The investigation may be conducted from the mechanical or from the experimental standpoint. We have confined ourselves, in the main, to the experimental point of view; and will begin in that way—endeavoring to show that the theory of variable velocities is not in harmony with certain observed properties of matter.

Let it be assumed that the prevailing ideas of the day concerning the corpuscular nature of gases are generally correct. Let the problem be to prove the falsity of the first and the truth of the second of the following two propositions:

PROPOSITION I.—"In a group of equal gas molecules in a steady state, at constant temperature, the individual molecules have very varying velocities—though the velocity of mean square remains constant."

PROPOSITION II.—"In a group of equal gas molecules in a steady state, at constant temperature, the individual molecules all have the same (or nearly the same) velocity."

For the sake of brevity, let Proposition I be called the theory of variable velocity; and let Proposition II be called the theory of uniform velocity. We will now present what seem to be six valid proofs of the truth of the theory of uniform velocity:

One Proof.—One of the best known of the experimentally determined laws of gases is that of Graham. Equation (1) states Graham's law—

$$(1)\ R : r = \sqrt{d} : \sqrt{D}$$

Where R is the volume rate of the diffusion of a gas having a density, D, and a molecular mass, M; and where, r, is the volume rate of diffusion of another gas, having a density, d, and a molecular mass, m—both gases being at the same temperature and pressure.

Graham's law is very approximately true; and maintains not only when the two gases diffuse into each other; but also, when, after mixture with each other in equal volumes, they diffuse into a third gas.

Another gas law, that of Avogadro, is stated in equation (2).

$$(2)\ M : m = D : d$$

Since the gases are at the same temperature the kinetic energies per molecule are equal—it being understood that the expression "kinetic energy per molecule" is to be interpreted as meaning either a fixed property of each molecule if the theory of uniform velocity be true; or a certain mean quantity if the theory of variable velocity be true. From the equality of molecular kinetic energies, at uniform temperature, we have equation (3).

$$(3)\ \tfrac{1}{2}MV^2 = \tfrac{1}{2}mv^2$$

in which V and v are the respective velocities of M and m.

Hence, $(4)\ MV^2 = mv^2$

and, $(5)\ M : m = v^2 : V^2$

and, $(6)\ \sqrt{M} : \sqrt{m} = v : V$

But from (2) we have—

$$(7)\ \sqrt{M} : \sqrt{m} = \sqrt{D} : \sqrt{d}$$

Hence, $(8)\ \sqrt{D} : \sqrt{d} = v : V$

and, comparing (1) and (8) we have—

$$(9)\ R : r = V : v$$

Equation (9) thus gives us the result that, temperature and pressure being constant, two gases diffuse into each other; or into a third gas at volume rates directly proportional to their molecular velocities. But, temperature and pressure being constant, equal volumes of all gases contain equal numbers of molecules. We can, therefore, restate Graham's law as in equation (10)—

$$(10)\ N : n = V : v$$

in which N and n are the numbers of molecules, of velocity V and v respectively, passing in opposite directions across a unit plane in unit time.

It is possible to state the law of diffusion still more rigidly. In figure 1, let the rectangule represent a vessel containing gases, G and g, corresponding to N and n respectively; and let these gases be separated by an imaginary plane.

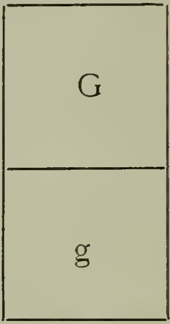

Figure 1.

Under the conditions given, and even though G be less dense than g, the molecules of the two gases begin to intermingle spontaneously. This intermingling or diffusion proceeds continuously until there has resulted throughout the vessel a uniform mixture of the two gases. This condition persists.

Now, since equal volumes of the mixed gas contain equal numbers of molecules, it follows that in any unit volume of the vessel there are as many molecules of either gas as there are molecules of that gas in any other unit volume of the vessel. The molecules continuing in motion, we have still enduring that migratory process which had produced the special equilibrium just noted. The equilibrium established is therefore a mobile equilibrium—conditioned upon the fact that across any unit plane in the vessel, and in unit time, there pass in opposite direction equivalent streams of molecules. Equation (11) therefore states the condition of equilibrium in diffusion; and is more rigid than Graham's law.

$$(11)\quad N : n = \Sigma V : \sigma v$$

in which Σ and σ are, in unit volume, the respective numbers of molecules. having velocity V and v.

Stating equation (11) verbally, it would read: "The number of molecules passing in one direction in unit time across unit plane is proportional to the number of molecules in unit volume multiplied by the molecular velocity." This result is, of course, exactly what might have been rationally expected; but it has.

as just developed, the greater advantage of experimental demonstration.

Cor. α. It will be seen from equation (11) that so long as Σ and σ remain sensibly equal, N and n are proportional to V and v only. Graham's experiments were of this type.

Cor. β. In the law of diffusion, as just developed, the constant of proportion is $\frac{1}{6}$ (see equation (14)). Hence the law may be stated is in equation (12)—

$$(12)\quad N = \tfrac{1}{6}\Sigma V$$

Very direct evidence of the truth of the theory of uniform velocity is to be found by an inspection of equation (11). In a mixture of two gases, the mobile diffusion equilibrium is known to be established when equal volumes have identical composition. It is this fact that proves the validity of the factors Σ and σ in equation (11). The validity of the factors V and v is proven by our interpretation of Graham's experiments, and by the rational character of the factors. True, the values V and v may be merely mean values; but, rationally, they must be arithmetic means. In a group of molecules having variable velocity, the arithmetic mean velocity does not coincide with the velocity of mean square; and hence the theory of variable velocity is discredited by the experimentally determined diffusion equilibrium. (See also the closely related discussion on page 394 of the theory of the pressure of a gas.)

Further Evidence.—With the help of the foregoing equation, we may now proceed to another experiment, which will lead to the same conclusion as that just stated. Imagine a rectangular prismatic vessel, represented by the diagram (Figure 1), into which is placed a volume of oxygen, G; and a mixture of equal volumes of hydrogen and carbon dioxide, g — G and g being separated by an imaginary plane. A process of diffusion would ensue—in which process molecules of hydrogen and molecules of carbon dioxide would pass into region G, while molecules of oxygen would pass into region g. But, as the velocity of the hydrogen molecules is greater that that of the carbon dioxide molecules, it follows that after a certain interval of time we would have in G more molecules of hydrogen than of carbon dioxide (equation (10)). It is therefore possible, by a process of diffusion, to divide a mass of gas having molecules of unequal velocity, into two portions—one portion being richer than the original gas in those molecules having the higher velocities; and the other portion being richer than the original gas in those molecules having the lower velocities.

Let the last experiment be varied by making G a certain volume of hydrogen; and g a certain volume of carbon dioxide. Now, if the hydrogen molecules have very varying velocities, it would follow that those hydrogen molecules having the higher velocities would begin to pass into the region g in greater profusion than those hydrogen molecules having the lower velocities. Also, those carbon dioxide molecules having the higher velocities would begin to pass into the region of G in greater profusion than those carbon dioxide molecules having the lower velocities. But there would be a greater number of hydrogen molecules passing into g per unit time than of carbon dioxide molecules passing into G in unit time. Thus: in the language of the theory of variable velocity, not only is the velocity of mean square greater for hydrogen molecules than for carbon dioxide molecules; but also there must be per unit volume of hydrogen, a greater number of molecules with velocities above a certain reference velocity, than of such molecules per unit volume of carbon dioxide. The mean kinetic energy of agitation of the molecules in region G would therefore decrease; while the mean kinetic energy of agitation of the molecules in region g would experience a proportionate increase. But this is the same as saying that the temperature of region G would fall; and the temperature of region g would rise. It is to be remembered that our last statement is conditioned upon the assumption that in a simple gas at constant temperature, the molecules have very varying velocities. If we assume, on the contrary, that the molecules have sensibly equal velocities, no observable temperature change could result. Here, then, is a means for experimentally determining which of the two assumptions is the correct one—for we can perform the experiment under such conditions that any temperature changes will be observed. If no temperature changes occur, we must conclude that the molecular velocities are sensibly uniform. If the indicated temperature changes do occur, we must conclude that the molecular velocities vary. I have conducted such an experiment by what would appear to be a satisfactory method; and I find no change in temperature.

The Special Experiment.—The apparatus and its operation are explained by figure 2, which is a schematic sectional elevation.

A, B, C, D is a thin-walled porous earthenware vessel.

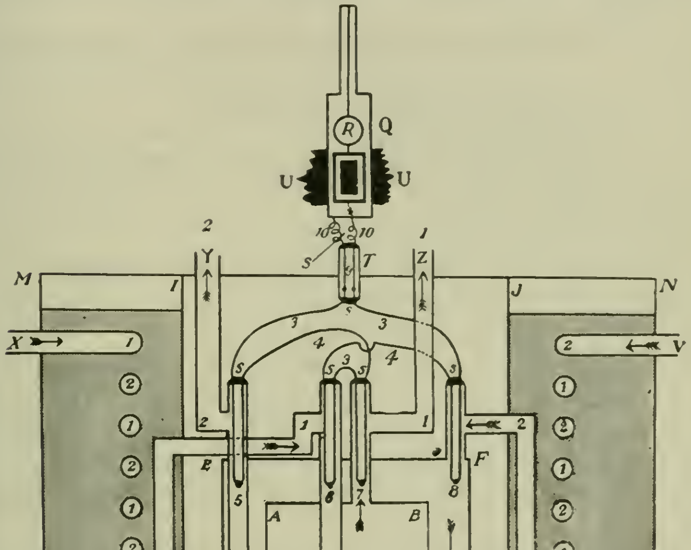

Figure 2.

I, J, K, L " copper vessel.
M, N, O, P " copper vessel,
E, F, G, H " glass vessel.

M, I, J, N " copper and asbestos-board cover,
W, W, W is water.

1 and 2, where shown in W, are two thin walled, small bore, brass tubes. These tubes are coiled, side by side, so as to form two helices.

1 and 2, where shown in places other than W, consist of glass tubing.

3, 3, 3, are lengths of German silver wire.

4, 4, are lengths of iron wire.

5, 6, 7, 8, 9, show joints—made by the "sweating process" (*i. e.*, by fusion, without solder).

10, 10, are lengths of copper wire.

Q, is a sensitive, reflecting, d'Arsonval galvanometer.

R, is the mirror of the galvanometer.

U, U, is the magnet of the galvanometer.

T, is a small glass tube—(To maintain an equal temperature on the two joints at 9. This arrangement has no part in the theory of the apparatus; but was found desirable in practice, because of the high sensitiveness of the galvanometer.)

S, S, S, S, S, S, are joints of sealing wax of high insulating quality.

The arrows (»——→) indicate two currents of gases; and show that when the apparatus is in operation, there are influent streams of gases at V and X—corresponding respectively to effluent streams of gases at Y and Z.

The operation of the apparatus will now be readily understood. The combination of wires and galvanometer shown, constitutes a very delicate, double differential thermoscope. For, if the two influent gas streams lack uniformity of temperature, they would tend to produce a thermo-electric current. Such current would be indicated by the galvanometer, unless the effluent gas streams preserved exactly the minute temperature difference of the influent gas streams—under which circumstances the thermo-electric effect, due to the influent streams, would be neutralized by the equal and inverse effect due to the effluent streams. It is to be noted that the difficulty sometimes experienced with thermo-electric couples—because of their relatively slow response—is obviated in the plan adopted here. The couples, being bathed in a continuous stream of gases, have ample time to rise or fall in temperature.

Let the influent gas at, V, have a density, d; and the influent gas at, X, have a density, D. Let D > d. The effluents at Y and Z, because of the passage of the gases through the apparatus, will not have the same composition as their respective influents at V and X. Moreover, the volume of the effluent at Z will be greater; and the volume of the effluent at Y will be less than the volumes of the respective influents at X and V—because of the continuous diffusive process taking place through the walls of the porous vessel, A, B, C, D; and because D is greater than d. Let the influent at V be a certain simple gas, G_1; and the influent at X be another simple gas, G_2. (By a "simple" gas is meant a gas having only one kind of molecules). Then (as shown in the preceding theoretical discussion) if the G_1 molecules have very varying velocities, and the G_2 molecules have very varying velocities, the temperature of the effluent at Z would be higher; and the temperature of the effluent at Y would be lower than the temperatures of the respective influents into the vessels A, B, C, D, and E, F, G, H. Such temperature alteration would be indicated by the galvanometer. Therefore, if we perform the experiment indicated, and obtain a galvanometer deflection, the hypothesis of varying molecular velocity in a simple gas at constant temperature is supported. On the other hand, if no deflection be observed, we must conclude that in a simple gas at constant temperature, the molecules have sensibly uniform velocities.

In my experiments I have used hydrogen and carbon dioxide. The apparatus shown in Figure 2, together with the generators, purifying and drying trains; and certain auxiliary apparatus were allowed to stand for twenty-four hours in a closed room, which was maintained at reasonably constant temperature. The apparatus was tested in various ways by interchanging the influents and also the thermo-electric couples; and by verifying the sensitiveness of the whole system as to minute temperature changes. I have obtained repeatedly the result that the effluent hydrogen stream neither falls in temperature; nor does the effluent stream of carbon dioxide experience a temperature increase.

The auxiliary apparatus, to which reference has been made, consists of a separate metallic water tank capable of being divided into two parts whenever desirable. The hydrogen and carbon dioxide were passed through coils of small brass pipe, immersed in the water in the tank, before being delivered to the apparatus shown in Figure 2. In this way, the temperatures of the two gases had a preliminary equalization. An indicating manometer system was also arranged, so that, by merely opening and closing cocks, the activity and uniformity of the diffusion could at any time be tested. The experiment itself was conducted at constant pressure—that of the atmosphere at the time of the experiment.

Further Evidence.—It would appear that many well known properties of gases are inconsistent with the theory of variable velocities. It may be advantageous to mention an example or two by way of illustration. It is well known that many gases having polyatomic molecules tend to dissociate sensibly upon sufficient elevation of temperature. In the kinetic theory of gases, an elevation of temperature means an increase in molecular velocity. But the theory of variable velocity requires at all times values for the velocity ranging from zero to infinity (See the quotations from Maxwell and Meyer given in this paper). In such a system the encounters between molecules with relatively high velocities would result in the disruption of those molecules. Gases would therefore exhibit anomalies in density such as have not been observed. True, the slower molecules might be supposed to have a tendency to polymerize. Such supposed compensatory process is made very improbable when judged by the theory of variable velocity itself—for the theory necessitates a greater probability for the very small velocities than for the very great velocities (See Meyer); and this would mean an over-correction by polymerization.

Let us take another pertinent example—typical of many well-known chemic systems: In a vessel, let two volumes of hydrogen be mixed with one of oxygen. Now, if the temperature be elevated to a sufficient degree, in any portion of the vessel, combustion proceeds, explosively, throughout the whole mass of the mixed gases—though no sensible reaction takes place at ordinary atmospheric temperatures. But elevating the temperature means merely increasing the corpuscular kinetic energy; and, therefore, if we have in the mixed gases, at all temperatures, all values for the corpuscular kinetic energy, as required by the theory of variable velocity, we should get explosive combination between the hydrogen and oxygen at ordinary atmospheric temperatures. Therefore, the known properties of the gas mixture are not in harmony with the theory of variable velocity.

Further Evidence.—Passing from the experimental verification of the theory of uniform velocity, it will now be shown that the same conclusion can be reached by an examination of the theory of variable velocity itself.

In O. E. Meyer's elaborate mathematical work on the kinetic theory of gases, we find that, while in general he employs the theory of variable velocity, he also makes the statements now to follow. (English Edition—pages 368,369, 370, 44, 49.)

"Very many proofs have been given of Maxwell's law. One such proof was attempted in the first edition of this book, wherein the law was put forward as the most probable of all conceivable laws . . . (but) the proof in its first form cannot be admitted as valid, and the doubts thrown upon it by Boltzman and von Kries must be held to be well founded. . . . I will therefore now lay the foundation of this proof in a way which will, I hope, be valid. Maxwell's law of distribution refers to the state which a group of gas molecules finally attains as its state of equilibrium in consequence of their encounters. . . . But, strictly speaking, it can only be reached when the number of gaseous molecules is . . . infinite. . . . if the number of particles is limited, Maxwell's distribution cannot exist at every moment . . . All values between 0 and ∞ occur for the components of velocity . . . the occurrence of the zero value is more frequent than that of any other given value. . . . This conclusion, however, must be false, as it can only extremely seldom happen that a molecule comes to rest in the midst of a swarm of molecules rushing rapidly about."

Meyers attempts to harmonize the uncertainties and contradictions just noted; and his efforts lead him to conclude (p. 52) . . . "That the values of the speed that occur with any considerable frequency are only slightly different from that of greatest probability, whence we might conclude that the idea of the molecules possessing equal speed is really approximately admissible." In other words, if we are to accept Meyer's words as just given, the theory of variable velocity in the abstract leads to certain difficulties. The methods which appear to him as necessary to be used to clear away these difficulties, only lead to the establishment of the theory of uniform velocity. It would also be very instructive to know the effect of a molecule having an infiinite velocity.

Further Evidence.—The kinetic theory of gases leads to the conclusion (Maxwell—Enc. Brit., 9th Ed., XI, 569, 570, Sec. 39-45) that the pressure, P, exerted by a gas upon unit area of the containing walls, is determined by the following equation:

$$(13)\ P = \tfrac{1}{3}MNV^2,$$

M is the mass of the molecule; N is the number of molecules in unit volume; V is the molecular velocity.

It would seem entirely admissible, after a cursory inspection of this equation, to say that V^2 *may* be only a mean value; and that among the N molecules concerned, the individuals can exhibit great differences in velocity, while the gas remains in a generally steady state at constant temperature. But before we make such an assertion, we must remember that the value of P is not the only thing to be considered. Certainly the value of P remains unaffected in the premises; but this fact forms no legitimate reason for asserting that the gas can have the property described. Equation (13) is merely the simplified form of equation (14), viz.:

$$(14)\ P = 2NMV\frac{V}{6}$$

The expression $\frac{V}{6}$ determines the number of molecular impacts on each side of unit cube in unit time by each molecule. This number is obviously functioned directly upon V. Hence it cannot be functioned upon the velocity of mean square unless the velocity of mean square be identical with V. The velocity of mean square is identical with V only when the molecules all have the same velocity. So, again we have the theory of uniform velocity confirmed by internal evidence in the kinetic theory of gases.

Further Evidence.—The theory of variable velocity may logically be divided into two parts—one of which must follow the other in this sequence: First, the proof that in a group of gas molecules the velocities *must* be variable; and, second, the mathematical investigation of the fact thus proved. This paper has no reference whatever to the second portion of the theory. The first part of the theory, as thus divided, would seem to be necessarily inductive in character—the proof being drawn from observed properties of matter. If this be so, then, no matter how profound and accurate may be the mathematical deductions of the second portion of the theory, the conclusions will not necessarily describe the properties of gases, except the proof given in the first portion of the theory be correct. We find only one proof, given by Maxwell, that in a group of gas molecules, the velocities must be very variable. In fact, only the merest mention is made of it (See page 383). The same proof is given very clearly in the work of Meyer, to which reference has heretofore been made (Pp. 41 and 42). We quote his words: " . . . if all the molecules had exactly equal speeds at any moment, this distribution of speed would be at once disturbed . . . consider . . . the case of a moving particle being struck perpendicularly to the direction of its motion and so that the direction of the blow passes through its center of mass; then the striking particle will cede part of its speed to the struck particle; which, as it experiences no resistance in the direction of the path it has thus far traversed, will retain its own motion undiminished, and, therefore, receiving in addition a further speed from the striking particle, will move more quickly than before collision, and in changed direction, while the other moves more slowly, since it must lose speed."

It is submitted that this proof is invalid—because the assumption that the struck particle "experiences no resistance in the direction of the path it has thus far traversed," is not in harmony with the facts that molecular action and reaction during any encounter require a certain time for completion; and that during this time interval, cohesion is operative. The cohesion would operate as a resistance, and not only would the struck particle be *pushed* by the striking particle, but also the struck particle would *drag* the striking particle.

A Theory of the Conduction of Heat in Gases.—We further propose, that whenever a previous difference in the molecular kinetic energies exists, then the stresses set up during the time of encounter would result in a torque, tending toward the equalization of the kinetic energies; and that the conduction of heat in gases is so explained.

CHEMICAL EVOLUTION.

The periodic sequence is a wide and valuable arrangement of the chemical elements; but it contains several apparent inconsistencies, not to mention many vacant seats. Among the confusing statements may be mentioned the reversed atomic weights of nickel and cobalt in one group, and of iron and tellurium in another. In the most recent and most accurate atomic-weight determination, nickel certainly is a little below cobalt; yet the chemical relation would seem to reverse this, putting cobalt nearer iron, and nickel nearer copper. Again, tellurium appears to be the homologue of sulphur and selenium; but the atomic weight determinations, while not strictly accordant, yet seem to put tellurium at 128, and above iodine, which is near 127. Now iodine is a well-defined halogen, falling into its place under fluorine, chlorine, and bromine; and tellurium, as mentioned above, seems a well-defined "metallogen." The discrepancies in these cases are not yet explained. They may serve as promising starting points for new discovery. They may involve contamination with small quantities of unknown elements. They may involve the new idea (borrowed from radium chemistry) of atomic disintegration, or concretion. But whatever the explanation, one conception is coming out more clearly with every new fact and theory, namely, the doctrine of the evolution of the chemical elements.

We are familiar with the hoary dignity of the nebular hypothesis, and with the more recent story of organic evolution; but back of the comparatively recent and youthful nebulous whirl—back in what may reasonably be called suns and stars are only cold-storage remnants of celestial history. young—at least in our part of the universe—back there somewhere, the elements were probably evolved from a simple form of matter by a system of their own. Imagination must guide us in reading between the lines of the Periodic Sequence this fascinating story of "the ether babies." Indeed, the first few volumes of this "Descent of the Elements" are missing, but we can fill out the story fairly well. There was a something, and it had parts. It was hot, hot beyond description. These modern refrigerators called suns and starts are only cold-storage remnants of celestial history. This something was squeezed to a solid. It broke off in shells—each shell forming a series long or short. Each shell stretched its elbows as it tore way from the parent mole, and so we find the remarkable order of varying atomic volume, with regularly increasing weight. The dream is so vivid—it wakes us to reality—but the echo of the dream is true all the same. Some day modern science will seriously and soberly consider this new aspirant for recognition in the history of evolution. The atom is waiting to tell his story to the chemical Lamarck, or Darwin, who has the ear to hear.

May the inconsistencies and omissions in the Periodic Sequence grow—and they are many—till the very gaps shall force out the reluctant confession. Confusion in atomic-weight order, confusion in rare earth identification and fractioning, confusion in allotropic form, confusion in argonoid element, in helium radiation, and in electron emanation, impossible distribution of atomic-weight, missing elements in one place, superfluous twins and triplets in others—it all means something. The story of the elements is yet to be written; indeed, carbon is the only one that has thus far accumulated very much of a chemistry. But when it shall be written—this new chapter of atomic birth and growth—men will give thanks for another page in the old Nature story which is never old.—*Engineering and Mining Journal.*

Stated Meeting, held Thursday, February 16, 1905.

On the Chemistry of Wool.

By Dr. J. Merritt Matthews,

Philadelphia Textile School, Lecturer on the Chemistry of Textiles and Pottery, Franklin Institute.

Although wool, and the closely related hair fabrics in general, play such an important part in our social and commercial economy, it is surprising to find that so little scientific work has been done by chemists in connection with the chemical constitution and properties of this important raw material which furnishes the basis of such a large number of industries. It is probably because wool is one of the commonplace materials of everyday life that the chemist passes it by and goes in search of some unheard of and unusable substance to which he may devote his labors of original research. We are, in fact, less acquainted, in a chemical sense, with some of the most commonplace substances of daily life than with many of the rare and less useful substances. The microscopic eye of the scientist is liable to pass by the large bodies near at hand and fix its attention on something far beyond the ken of common things.

In a study of the chemical constitution of the wool fibre, at the very outset a distinction must be drawn between the raw fibre as it occurs in the fleece and the purified fibre as it is used for purposes of manufacture. The fleece, as it comes from the back of the sheep, contains many other substances besides the fibre proper. In the first place, a considerable though varying amount of miscellaneous foreign matter and dirt is always associated with the fibre. This amount may vary from five to twenty-five per cent. of the weight of the fleece. Apart from this material, however, there is always associated with the fibre in a natural manner a large amount of grease, together with the residue resulting from the dried-up perspiration from the animal. The greasy matter, known as wool-fat, is a natural excretion from the sebaceous glands of the skin located around the hair-root of the fibre. The function of this greasy matter is to prevent the fibres from becoming matted together in the fleece by surrounding them with a rather thick layer of soft fatty substance. In other words, the wool-fat is really a product closely related to the fibre itself, and is a physiological concomitant of its growth. This fat, however, does not in any sense form an integral part of the structure of the fibre, being merely an external coating on its surface and its removal therefrom, which takes place in the process of wool-scouring, does not in any manner affect the physical or chemical properties of the fibre. The dried-up perspiration, or so-called "suint," which also occurs in rather large amount in the wool fibre, differs from the wool-fat in that it is not in any special manner related physiologically with the growth of the fibre. It is merely derived from the perspiration naturally excreted by the sudorific glands in the skin, and which, by reason of the heavy layer of wool on the animal, has no chance of being removed except by evaporation, which of course, leaves within the fleece all the non-volatile solid constituents occurring in the perspiration. This dried-up residue is usually more or less mechanically held by the greasy matter coating the fibre, and is removed together with the latter in the scouring of the wool. The suint is distinguished from the wool-fat in that it is soluble in water, and consists for the most part of potassium salts of various organic acids. The wool-fat is chiefly composed of cholesterol (which is a monatomic alcohol having a high content of carbon atoms) and its related substances. The amount of actual grease present in the raw fleece of the sheep varies from eight to twelve per cent. while the amount of dried-up perspiration varies from fifteen to thirty per cent. The wide limits of variation in these substances are caused by difference in the breed of the sheep, difference in climatic conditons, manner in which the sheep are reared, etc. Taking all the materials existing in the raw fleece into consideration, we will find that the actual amount of fibre present varies from fifty to twenty per cent, with probably an average of thirty-five per cent. for the general grades of wool.

Coming now to a consideration of the fibre proper, we will discuss its general chemical behavior as at present determined. In the first place, wool belongs to the general class of proteoid substances, and is closely related, if not in fact almost identical in composition with, the various skin tissues, including feathers, hair, horn, and leather. In other words, it is chemically related to gelatin and albumin. It is not, however, soluble in water, nor the ordinary solvents, although when heated for some time with water under pressure it is gradually decomposed and dissolved. In common with other albuminous substances, wool is evidently an amido-acid. The fact is deduced from many considerations: in the first place, ammonia is to be found among the products of the destructive distillation of wool; again, wool is rather easily hydrolysed by the action of dilute alkaline solutions; also, wool readily combines with acids, and even on boiling with dilute sulphuric acid it is possible to find considerable traces of ammonium sulphate in the solution. Further than this, the presence of an amido group in the wool fibre is strongly evidenced by the fact that on treating wool with an acid solution of nitrous acid and afterwards with a phenolic body, certain well defined colors are obtained analogous to the bodies produced by this same diazotising reaction on ordinary aromatic amines. This method of applying the diazo reaction to wool is interesting, and by the use of a variety of phenolic and amido bodies as developers for the diazo compound of the wool a variety of colors may be produced on the fabric. In such instances the wool acts as its own dyestuff, or rather, it acts as the material from which the dyestuff itself is made.

The presence of an amido group in the wool fibre is also evidenced in the many ways in which wool exhibits its well-defined basic properties. In the first place, wool combines with and neutralizes a considerable amount of acid; for instance, if wool be boiled in a solution of sulphuric acid for some time, and then thoroughly washed until the wash waters are perfectly neutral, by a quantitative determination, the amount of acid neutralized by the wool may be readily ascertained. In this manner it is possible to obtain what may be termed the "coefficient of acidity" of wool. This is a number representing the amount of caustic potash, expressed in milligrams, neutralized by one gram of wool. This coefficient of acidity for wool, together with other related albuminoids, may be given as follows:

Wool = 57; Silk = 143; Albumin = 20.9; Gelatin = 28.4.

The basic nature of the wool fibre is furthermore evidenced by the readiness with which it combines with acid dyestuffs, in which reaction it appears that there really exists some sort of chemical combination between the acid constituent of the dyestuff and some constituent in the wool.

In common with other amido acids, wool also exhibits in some degree the properties of an acid. It will absorb alkalies from solution and effect a partial neutralization of them. Owing to the fact, however, that it is not possible to determine with any degree of exactness the amount of alkali actually neutralized by the acid component of the fibre, it is not possible to furnish a coefficient of alkalinity for wool corresponding to the coefficient of acidity. This is caused by the fact that alkalies affect a decomposition of wool before the acid nature of the fibre is completely saturated. The fact, however, that when wool is treated in the cold with concentrated solutions of caustic potash there is a considerable absorption of the alkali by the fibre which cannot afterwards be removed completely by washing, would indicate a neutralization of the alkali by some acid component of the fibre. It has also been found that wool which has been thus treated has a lessened attraction for the general class of basic dyestuffs. In this connection, it may also be said, from the very fact that wool does exhibit in its normal condition, a considerable affinity for the basic colors, would be an indication of its containing an acid group in its constitution.

It is hardly probable that the wool fibre as a whole can be considered as a homogeneous chemical compound. I am led to this conclusion not only by a study of the varying chemical behavior of wool towards many reagents, but also by a consideration of its physical structure. In the latter respect the fibre is composed of three well-defined parts: an external sheath of flattened and hardened cells, an under layer of long fibrous cells which make up the major portion of the fibre, and finally a central layer of round medullary cells. From the very fact that these different portions of the fibre possess separate structures and functions, it would be reasonable to expect to find them possessing difference of chemical constitution. As it is an exceedingly difficult matter to satisfactorily separate from one another these different portions of the fibre for purposes of chemical analysis and study, it is not possible to state just what these chemical differences may be. I have found, however, in the study of the action of alkalies on the wool fibre, that the external layer of cells, which furnishes the scales on the surface of the fibre, appears to be attacked in a somewhat different manner from the rest of the fibre; also in the action of the majority of dyestuffs on wool, I have found that these external cells are generally not dyed like the inner layers of cells. Although I am aware that these differences may be due more or less to differences in the physical structure of the cells, nevertheless, they are more likely to be due to the difference in chemical composition.

Another consideration which leads me to the conclusion that wool is not a homogeneous chemical compound is that by the action of alkalies a certain amount of one of its components, sulphur, may be removed without any apparent physical disintegration of the structure of the fibre. Also, in different qualities and kinds of wool, the percentage of sulphur present in the fibre is quite a varying factor. Whether this chemical difference is located in the substance of the different characters of cells to be met with in wool, or whether it is due to differences in the composition of the cell-wall as compared with the contents of the cells, we do not at present know, as it has not been possible as yet to satisfactorily separate the substance of the cell-wall from its contents. The chief hope of any scientific work in this direction lies in a study of the micro-chemical reactions of wool with various reagents.

ACCIDENTS ON AMERICAN RAILWAYS

Are attracting so much attention just now that it is particularly interesting to review the figures given in the report of the Interstate Commerce Commission for the year ending June 30, 1904. There were 43,266 employes injured and 3,367 killed in 1904, as compared with 33,711 injured and 2,516 killed in 1902. The figures for 1903 are intermediate between those for 1902 and 1904. In 1904 there were 8,077 passengers injured and 321 killed; in 1902, 6,089 injured and 303 killed; in 1903 there were 6,973 injured and 321 killed. The increase in the number of deaths of passengers in train accidents in 1904 compared with 1903 is 64½ per cent. There were ten unusually disastrous accidents during the year. The number of deaths resulting from these accidents, eight of which were collisions, is about 23 per cent. of the total number killed in all the train accidents of the year, which comprise over 6,000 collisions and 4,800 derailments. Although there has been earnest discussion of the subject in the public press, it is noticeable that the very magnitude of the question involved appears to have produced some confusion, and in the multitude of causes assigned the real question in many cases has been lost sight of. The paramount requirement, as pointed out in the last annual report, is an effective measure for the prevention of collisions.

Book Notices.

A Practical Method of Adjusting a Modern Gun and Determining its Errors in Azimuth, Elevation and Vertically as well as the Errors of the Telescopic Sight. By Otto von Gelden, M. Am. Soc. C. E., Civil Engineer. (Circular No. 4. 12 mo. paper, 21 pages.) Headquarters Pacific Division, San Francisco, Cal. Published by command of Major-General MacArthur, Washington. Government Print. 1904.

This pamphlet describes in detail a method of adjusting and calibrating the training and elevation arcs of a modern sea-coast gun.

The author points out the similarity between the motions of the gun and those of a transit and describes the method of training the gun in azimuth to correspond with the setting of the transit and comparing the readings. From the readings obtained from a number of stations an error curve of the training-arc angles is plotted. The elevation-arc is tested for one position only from each station.

The description is very clearly written and should prove of value to those interested in artillery engineering. L. E. P.

Le Calcul Simplifié par les Procédés Mechanique et Graphique. Historie et description sommaire des instruments et machines á calculer, table , abaques et nomogrammes. By Maurice d'Ocagne, Ingenieur des Ponts et Chaussées, Professeur á l'Ecole des Ponts et Chaussées, Répétiteur á l'Ecole Polytechnique. Second Edition, entirely reset and considerably enlarged. 8vo, cloth, 225 pages, 73 figures. Gauthier-Villars, Paris, 1905. (Price, 5 francs.)

The literature of calculating machines and other devices for lessening the labor of numerical computation is not in an easily accessible form and the work before us embracing, as it does, in small compass a history and concise but not too brief description of the more important forms of such instruments brings within easy reach a comprehensive and up-to-date view of the entire subject.

The first three chapters, comprising 128 pages, are devoted to mechanically operated devices, from the most simple types, in logical order, to elaborate and complex machines whose principles and important details of mechanism are described at considerable length.

The remainder of the work treats of graphic computation by geometric construction, by diagrams in rectangular coördinates, by diagrams in distorted coördinates of which the well known system of logarithmic coördinates is a special case and, lastly, by a system of representing in one plane the simultaneous values of three-variable expressions by the use of graduated lines. This last feature is of particular interest in its application to technical work, but to one unacquainted with the development of the process employed the description is not sufficiently full. The author's aim, however, appears to present this part of the subject in outline only, referring to his Traité de Nomographie for a full discussion.

The large number of foot-notes of bibliographic references is a particularly commendable feature. L. E. P.

Chemical Analysis for Glassmakers. Containing methods of analysis for clays and other silicates, which will be found useful for the pottery industry. By Edward C. Uhlig. B.S., M.A.C.S.. etc. (8vo. pp. 136.) Pittsburgh: Kaufmann & Gauding. N. D. (Price. $5.00.)

The author of the above-entitled book has endeavored to explain to those engaged practically in glassmaking the essential principles of chemical analysis, to enable them to exercise a scientific supervision of their works. It should prove a useful hand-book for those for whom it is intended. W.

Text-Book of Organic Chemistry. By Henry Leffmann, M.D., and Charles H. LaWall, Ph. G., (with illustrations and experiments.) Philadelphia: P. Blakeston's Son & Co. 1904. (Price, $1.00 net.)

The authors present in this volume in exceedingly compact form a compendium of organic chemistry covering those features of the science which will be likely to prove most useful in its applications to pharmacy, medicine and the industries. W.

Laboratory and Factory Tests in Electrical Engineering. By George F. Sever, Adj. Prof. Electrical Engineering, Columbia University, and Fitzhugh Townsend, Tutor in Electrical Engineering. Columbia University. (8vo, pp. xii + 236.) New York: D. Van Nostrand Co. 1904. (Price. $2.50 net.)

This book represents substantially the course of laboratory practice required in the Electrical Engineering Course at Columbia University. It will be found helpful, not only to students of electrical engineering, but also to the great number of those engaged in the higher branches of the electrical profession. W.

Sections.

Chemical Section.—A joint meeting of the Chemical Section and the Philadelphia Branch of the American Electro-Chemical Society was held this evening, Thursday, January 19th, at 8 o'clock. Present, 42 members and visitors. In the absence of the President, Prof. G. A. Hoadley was called to the chair.

The evening was devoted to the reading and discussion of a paper by Prof. Wilder D. Bancroft, of Cornell University, on "The Chemistry of Electro-Plating.

The speaker illustrated his remarks with the aid of specimens of plating with various metals, lantern slides and photo-micrographs, exhibiting differences in structure of the deposited metal, due to changes in the chemical constitution of the bath and physical conditions of deposition.

The subject was freely debated by Messrs. Carl Hering and Charles J. Reed, Drs. H. F. Keller and Wm. H. Wahl, Prof. George A. Hoadley and the author.

The thanks of the meeting were tendered to Professor Bancroft, and the session was adjourned.

Wm. H. Wahl,
Secretary pro tem.

Stated meeting held Thursday, February 16th, 8 P.M. Dr. E. Goldsmith in the chair. Present, 15 members.

Mr. John Howard Graham, Central High School, Philadelphia, was introduced by the Chairman, and read a communication on "The Determination of Sulphur in Iron Ores."

The paper was discussed by Dr. W. J. Williams, Dr. H. F. Keller, Dr. E. Goldsmith and the author.

The speaker was given a vote of thanks for his interesting communication.

In the absence of Dr. J. Merritt Matthews, his paper on "The Chemistry of Wool," was read by the Secretary. Discussion was deferred.

Both papers were referred for publication.

A resolution was passed requesting the Committee on Sectional Arrangements to put to a vote of the members the question of consolidating the Chemical and Physical Sections, and the annual election of officers was postponed until the result of the vote had been ascertained.

WM. H. WAHL,
Secretary pro tem.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting*, held Thursday, January 26, 8 P.M. Mr. Charles Day in the chair.

Present, 143 members and visitors.

The following officers were elected: President, Charles Day; Vice-Presidents, H. W. Spangler, Kern Dodge; Secretary, D. Eppelsheimer, Jr.; Conservator, Wm. H. Wahl.

The meeting was devoted to a discussion of the subject of "The Steam Turbine," and was opened by Prof. Spangler. The following persons participated: Prof. L. C. Lœwenstein, Lehigh University; Mr. J. A. Lafore (representing the De Laval Steam Turbine Company); Mr. Richard L. Rice (representing the General Electric Company); Mr. J. H. Macalpine, W. C. L. Eglin and Francis Head and others.

The Chairman tendered the thanks of the meeting to the speakers of the evening and adjourned the session.

WM. H. WAHL,
Secretary pro tem.

Stated meeting held Thursday, March 2d, 8 o'clock. Mr. James Christie in the chair. Present, 84 members and visitors.

The first communication of the evening was presented by Prof. W. F. M. Goss, of Purdue University, Lafayette, Ind., on "The Application of Superheated Steam in Locomotive Service," which the speaker illustrated by the exhibition of a series of lantern photographs. The paper was freely discussed, and is referred for publication.

Mr. G. H. Mumford, of the Tabor Mfg. Co., Philadelphia, read the second communication, on "Foundry Moulding Machines," which was likewise illustrated.

The speakers were given the thanks of the meeting, and the session was adjourned.

WM. H. WAHL,
Secretary pro tem.

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Mining and Metallurgical Section.

Stated Meeting, held Thursday, February 2, 1905.

The Testing of Cast Iron.

Dr. Richard Moldenke,

Secretary to the American Foundrymen's Association.

[Abstract:—Within the past decade or less radical changes have been introduced into foundry practice. Scientific methods have replaced rule-of-thumb methods, with correspondingly great advantages, in respect of economy in operation and certainty in quality of product. The present paper gives a concise summary of modern practice.—The Editor.]

But few of the materials of construction have received as much attention in recent years as cast iron; and indeed it was high time that this study was taken up, for in no one branch of the great iron industry was there so much need of light.

It goes without saying that America began with this work at an early stage, got substantial results at the very start, and with the usual practical turn all such matters take here, it was not long before the phenomena observed were classified, and the knowledge derived applied to daily practice. Thus we are to-day gradually working toward uniform methods for the production of the highest grades of material for all classes of castings.

The best results were, of course, obtained with the specialties, for here an individual investigator had at his command a wide range of experience in one particular line and with his special materials. For instance, the modern cast-iron car wheel is almost perfect in the process of making and the quality of work turned out. Chilled rolls, the malleable casting, ingot molds, stoves, pipe, gun iron, and specification castings for Government and other work; all these special lines at the present time exhibit a perfection in the state of the art considered impossible not so long ago.

The natural result of all this effort is that the consumer learns with the producer, a little slower perhaps, but nevertheless sufficiently to enable him to discriminate between the methods and results of the progressive founder, and the man who does not care, or is content to do things as his forefathers did. Hence, specifications are the order of the day. In the case of cast iron, the movement for standard specifications for the products of the industry emanated from the foundrymen, and not the buyers. This was because foundry owners were quick to note that giving a good grade of material voluntarily meant the staving off of unreasonable demands otherwise made by purchasers not fully up to date in foundry practice.

It was not long after the nature of cast iron was better understood that the American Foundrymen's Association, which freely encouraged all these investigations, requested the American Society for Testing Materials, the clearing house of the Nation's industrial life, to promulgate standard specifications for testing cast iron and finished castings. Foundrymen, metallurgists, and representative buyers alike worked on this problem with the result that to-day there have been adopted standards for the purchase and sale of foundry pig iron, cast iron pipe, locomotive cylinders, malleable castings; and there are pending specifications for the testing of cast iron in general, and cast iron car wheels.

As a side line in the testing of cast iron, the materials used in its production are also coming in for their share of attention. Thus we have just in process of organization an important committee on preparing standard specifications for the purchase and sale of foundry coke. The adoption of such a standard, which shall at the same time be fair to the coke-maker, and the foundryman, will mean a great stride forward, and one more source of constant annoyance will have been mitigated, if not altogether removed. Those who are not right in touch with actual conditions cannot realize the damage caused by high sulphur coke just when castings of special strength or softness are wanted.

Eventually we may see molding sands and facings the subject of standardization. Indeed, for those who have given these minor and yet important matters close study, the day that intelligent and effective specifications are devised to take care of them, will be a happy one.

With these general remarks we can now take up in more detail the characteristics of cast iron upon which an intelligent and correct system of testing it can be based.

The strength, appearance of the fracture, resistance to cutting tools, density, melting point, etc., of a cast iron depends upon the relative proportion of graphitic and combined carbon present, both together making up the total carbon. That is, if the total carbon is nearly all present in the graphitic or uncombined state, the iron will be soft, in fact, a mild steel with the intersticies between the crystals filled with graphite. The fracture will also be gray or almost black. If, on the other hand, the carbon present is all or nearly all combined, the iron will be white or mottled, hard, so that tools cannot touch it, and not good for the ordinary purposes cast iron is supposed to be used for. Everything else being normal, carbon in cast iron is at the same time its most important and yet its most easily influenced ingredient.

We have only to run up the silicon content of a cast iron to change an otherwise white iron to a gray one; or leaving the silicon low, to cool the metal from the liquid state very slowly, to produce the same result. Then again, if we take a high silicon iron and cast it against an iron chill plate, we prevent the separation out of the graphite, by not giving it time to do so before the metal is solid, and the result is an iron which is at least very closely grained and light gray, if not actually white at the point of contact with the chill. The same condition of things, though in a very much smaller measure, is observed by pouring an iron exceedingly hot.

The other elements present in cast iron naturally have their effect also, and attention is called to this fact only in so far as it will explain the reason why these elements, together with the carbon, and also the relative proportion of pig iron and scrap, the method of melting, and the subsequent manipulation in the foundry; all together have given us at least twelve distinct classes of iron castings, based on the characteristics of the metal only, and some forty-three general classes of castings, the iron in each of which is a little different from that in the others.

Without going further into this, it will suffice to say that unless due regard is given the composition and the peculiarities of heat treatment as outlined above, in any system for testing cast iron, it will not be worthy of our confidence.

It will, of course, be understood that when dealing with extremes in composition of a cast iron, in the rapidity or slowness of the cooling, and the temperature of the pour, or in the combination of two or more of these points, that the phenomena observed as to strength, appearance, and general character of the resulting castings, are very strongly apparent. Where, however, the composition of the iron is normal, that of a gray one, where it is cast neither too hot nor too cold, and is let to cool down under ordinary foundry conditions, one does not notice half a dozen different varieties or iron in the same casting.

To illustrate this point by an example directly from the foundry testing room. A test bar one-half inch square and broken transversely on supports 12 feet apart, is much used by the stove trade, to get the strength and contraction measurements. This bar is claimed by its friends to be infallible for all uses except perfectly white iron. Yet it so happens that no bar is so easily affected in its arrangement of the carbon content as this one, by the greater or less dampness of the molding sand, the temperature at which the iron is poured, not to speak of the composition of the iron itself, which makes a small bar very sensitive. A ladle full of hot iron from which a mold is poured, then let stand for a while until pretty dull. Then another mold poured for the same sized bar, will give two tests of different strengths and different contraction measures. The stove founder had better make his tests on bars which are larger in section and hence not so influenced by inequalities in foundry practice.

If test bars were made round instead of square, one very evil effect would be obviated. The chilling of the edges by quick cooling always produces in them proportionally more combined carbon than would be the case in a round section. The chilled edges are therefore harder, and at least artificial as regards the legitimate nature of the iron. In some specifications a broken square bar is turned up round for further tests. This, it will readily be seen, leaves the resulting round bar with four hard and four soft places in the surface of the cylinder. Just how a bar of this kind can truly represent the iron in the castings it would stand for, is an open question.

Suppose, then, we make a test bar round instead of square, and quite large in section. Let us say over one inch in diameter. The metal in the mold will then have time to cool normally, the dampness of the sand will not affect it so much in the first place, and if the metal has been cast unduly hot, it has a chance to lose its excessive heat before much of it has set against the surface of the mold. Chemically speaking, the silicon in the iron has a chance to get in its work, throwing out the proper amount of graphite at the moment of set, and while the skin of the casting will be finely grained, and the interior coarsely so, the structure changes uniformly from the surface inward, without the extra complication of chilled corners thrown in. The general trustworthiness of such a round large bar is certainly much greater than a little square one, which may be made to show anything you like by suitable manipulation.

Now to go one step further. If a test bar or any flat casting is molded up horizontally and cast in that position, the metal flowing into the mold through the comparatively narrow gate, will first roll along the bottom of the mold, heating up the sand there, but cooling the iron. Now, as more iron is forced in, the cold iron is pushed upward by it, eventually touching the cold sand in the top of the mold, while the last hot metal sets on the hot sand of the bottom. The result is a considerable difference of conditions in top and bottom of the casting, and this is quickly noticed if the material is tested cope side up, or cope side down.

To avoid this trouble, the only rational method of molding would be to get the test bars standing upright, and to flow the iron in either from the top, or to let it run upward from the bottom. This latter method gives the best results, but is too expensive for ordinary foundry use. If carefully poured from the top, especially if the bottom of the mold is rounded up, so that the stream of iron falling in does not shot itself, the bars made leave nothing to be desired. We now have round bars of large diameter cast vertically, as more reliable when compared with smaller square ones cast flat.

The next step to be considered is whether the mold cannot be made so that its nature does not artifically strengthen or weaken the test bars. This is done by subjecting the ordinary green-sand article to a drying process. As all of our foundries are equipped with drying facilities for their core work, this provision for the greater accuracy of a test bar in representing the metal it is cast for can be easily carried out. A flask for test bar purposes should therefore be made of iron, so that the mold can be dried in a core oven, and cooled before casting.

Perhaps we should before going further discuss the very idea of testing cast iron as it is carried out to-day, so that the reasoning therefor may be understood. The only way to know whether a casting will stand up under the service strain it is supposed to undergo, is to put it under such conditions, and see if it will pass muster. For safety, we always put it under a test at least 25 per cent. to 50 per cent. more severe. Now we cannot test the thousands of castings that are made daily, nor are many of the castings made in such a shape that we can apply any tests which will give us the desired information. Some, however are, such as the car wheel, and here three are taken from a given lot of 103, and broken under what comes as near to service conditions as can be made possible, short of actually putting them in a train and wrecking this by excessive severity.

Again pipe may be put under bursting pressure, car couplers may be pounded by drop weights, etc., but for the great majority of castings no way can be devised to give us an inkling of what they will actually stand by a direct test.

For this reason it has come to be conventional to take bars of cast iron, of the same ladle as the castings, or at least from the same heat, at regular intervals. These bars of iron are broken either transversely, or under tensile strain, or both, and from them we learn what was the quality of the iron which went into the castings. It stands to reason that when we are put to it to judge our castings by another casting, different in shape, and tested under conditions different from what will be the case with the original work, we certainly do not want to deceive ourselves in any particular about what we are doing. The key-note of American testing practice, so far as cast iron is concerned, is, therefore, to give the iron put into the test bars the very best chance possible to exhibit its properties just as they are, neither artificially strengthened, nor weakened, by irregular foundry manipulation. If the iron thus cast shows up to be of first-class quality, the castings the tests are to stand for, will also be of good iron, and it should, in fact must be, left to the knowledge of the founder of his business, to see that the molding and pouring conditions for the castings are such that the best possible results are obtained.

The wise founder, therefore, will always open his laboratory fully to the inspector of the purchaser, it being his safest guarantee that the greatest possible care is taken to have none but the best material to start with, and none but the best practice to use it.

Some further items on the test bar question must not be forgotten. In the first place, it is important that the bars be not rumbled, or treated otherwise than simply brushing them off when taken from the sand. Your fellow-townsman, Mr. Outerbridge, was the discoverer of the remarkable strengthening effect of the rolling barrel on castings, the molecules of which are brought to their normal positions by this rattling process.

The speed of testing is also important, for a bar broken unduly quick is apt to show higher figures than one tested unduly slow.

Now, as to the pressure put on the test bars in breaking them. The transverse test is always preferred by those who are familiar with the characteristics of cast iron, not because the tensile test is not better, but because the difficulties in getting a fair tensile test on cast iron are so great that the slightest imperfection in the machine grips, or the skin of the bar, etc., will give a side pull, which reduces the record so abnormally that an otherwise good iron will be condemned. The transverse test also dealing with figures about one-tenth as large as the tensile requirements, allows every foundryman to have his own small machine. He can, therefore, make daily tests for the purpose of checking his work, and can thus, if he wishes it, steadily improve his output in quality.

Another point that must be considered in the preparation of the test bar which is to be used under the tensile test, is the necessity of removing the skin. Every casting has the surface covered with very fine hair cracks, to a greater or less extent, accordingly as the metal is hard or soft. Now in pulling apart such a bar, rupture will take place much sooner at one of these cracks than at any sound place. As these cracks are never deep, but in the skin only, cutting off enough metal to get below will remove this danger. For this reason the broken parts of a transverse bar after the test can be turned up to remove the skin, and then pulled under tensile strain.

We have now gradually developed the ideal conditions under which any system for testing cast iron, and the preparation of test bars, should be undertaken. Perhaps we may have omitted some details inadvertantly, but it is hoped not. We must now take into account certain commercial limitations, which cannot be avoided, otherwise even the best system will not be used. First of all, any system for testing cast iron which is to be the basis of specifications must not be burdensome to the founder, while amply protective for the buyer. That would mean that the necessary molding, pouring, and finishing should be done without interfering with the making of the actual castings. The number of test bars must not be too great, and they should be cast from the first and the last of the heat, and enough between to make a given number of tons of castings represented by sufficient bars to prove them up. All these bars should be tested, and if only one bar of the two or more made in each mold passes, this should be sufficient. However, one must pass out of every mold poured, otherwise the iron would be open to suspicion. As the ordinary limit of the commercial transverse testing machines in the foundry is about 5,000 lbs., this figure should not be exceeded in designing the bar. For tensile tests this is a different matter, as the bars in any case would have to go to the very best testing laboratories available. In fact, where a tensile test is demanded, the work entailed is so onerous and expensive that no founder should be expected to stand it, and hence it should be charged to the buyer. The same can be said in cases of dispute, where both buyer and seller claim to be right. On calling in an outside expert, satisfactory to both parties, the loser should always pay the bill. This is mentioned merely by the way, as it forms the substance of one clause in the Pig Iron Specifications recently adopted.

A further commercial limitation is the speed of testing. This should be as high as it can, consistent with correct reresults. Elaborate experiments have been made along these lines, and the conclusion arrived at is that a rate of application of the load for 30 seconds to give a deflection of 1-10 inch is about right for cast iron. As already stated further above, when tensile tests are demanded, the test pieces should be turned up from the ends of the bars broken in transverse test. This saves the casting of extra bars. Of course it is understood that the founder can cast as many extra bars as he likes for his own information, as it is at his own expense, but once he knows his own record from daily observation, he will not need to do this, except perhaps for Government work, where usually the price received allows of all kinds of precautions.

While considerable stress has been laid on the total carbon in its two divisions, one other element should come in for some notice also, as it has a far reaching effect on the strength and hardness of a casting. This is the sulphur. When this element is present in excess, we have all kinds of trouble in service. It is therefore necessary to limit the quantity allowable in castings, and this limit depends upon the thickness of the work. A heavy casting can carry more sulphur than a small one, for in the latter the hardening effect is more perceptible. While sulphur, therefore, must be made an item in all cast iron specifications, the other elements, carbon included, need not be, as the combination of iron with silicon, carbon, manganese, phosphorus, and sulphur, as found in the varieties of cast iron, gives evidence of the amounts present by the strength of the bars under test. A specification which has the physical requirements prescribed, and also takes into account all the chemical ones, would be burdensome. On the other hand, if only chemical specifications were given, and the physical requirements left out, no account would have been taken of irregular or incorrect heat treatment in the foundry.

Another matter in which commercial considerations had to be reckoned with more than was desired from the standpoint of scientific testing, was the selection of a standard test bar. The correct diameter of a test bar for a given class of iron can be readily learnt by casting a series of round bars in dry sand ranging from half an inch upwards to about four inches in diameter. On breaking them transversely, the fracture should be noted. The small bars will be very closely grained and dense; in the case of low silicon irons they will even be white. As the diameters grow larger, the grain opens and soon a point is reached when open spots appear in the structure. The metal at a point just before this happens will be in its best and proper condition. For instance, take chilled roll iron. The small bars are all white. As they increase in size the metal becomes mottled, then gray, though finely grained. Not until a diameter of three inches is passed will the metal begin to show very slight signs of irregularity in the density. Hence a bar or test purposes should be at least three inches in diameter. But where will a testing machine be found in common use to break such bars transversely with supports 12 inches apart? Good metal of this kind will run near or over 100,000 lbs. for this test. Again with for ordinary castings the critical diameter is about 1½ inches. Yet here also the transverse strength exceeds 5,000 lbs., or the limit of the ordinary testing machine. Hence in the so-called "Arbitration Bar," adopted by the Committee which has studied this question, a bar 1¼ inches in diameter and 15 inches long has been selected, to be tested transversely on supports 12 inches apart.

In selecting this distance for the knife edges, we differ radically from German practice. Over in Europe they are inclined to adhere to the old method of taking very long bars and bending them slowly. We used to do this here ourselves, and the day is not so long past when a five-foot bar, one inch square was treated to a 500 lbs. weight suspended at the center. If it stood up, the castings it represented passed, if not, they were rejected. One can readily imagine how slowly and carefully the foundryman lowered the weight from the crane upon the bar, and how carefully the chain was examined so that no unexpected kincks might open up at a critical time, making a weak bar snap untimely, where it would otherwise stand up all right with the proper nursing.

My own investigations on bars of various lengths and of the same cross-section have shown me very conclusively that the longer the bar, the less sensitive it is to bending and shock. As cast iron, unfortunately, is the very worst material that can be used under shock, and as no castings in ordinary service are not subject to it, a test should take this into account. With the bars very short, say on 12-inch supports, ample opportunity is given to see how the metal stands the fairly quickly applied load. If, however, the load is put on slow and the bars are very long, time is given for the molecules to adjust themselves to the changing conditions, and the result is an artificially good value.

In concluding, it might be well to run over the salient points of the standard specifications for cast iron, soon to be issued. They will show how well the arguments advanced in this discourse have been considered by the Committee above referred to.

Cupola metal is supposed always to be used unless furnace iron is specified.

Castings are divided into three classes, those below ½-inch in thickness being called light; those between ½-inch and 2 inches being medium, and those above, thick. The sulphur content in these classes shall not run over .08, .10, .12, for the light, medium, and thick castings. Similarly the transverse breaking strength of the arbitration bar shall be up to 2,500, 2,900, and 3,200 lbs. for these classes, while the tensile strength, if demanded, is to be up to 18,000, 21,000, 24,000 lbs. per square inch. In the case of the transverse test, the deflection shall in no case be under 1-10 inch before the bar breaks.

The sulphur determinations are to be made from these broken pieces.

The castings must be true to pattern, free from cracks, flaws, and excessive shrinkage, but otherwise in finish as specially agreed upon, for it may often happen that an extra fine finish is not wanted, and the price is made accordingly.

The inspector is to be given all possible but reasonable facilities for assuring himself that everything is all right.

Now, as to the "Arbitration Bar." Two sets of two bars shall be cast from each heat, one from the first and one from the last of the iron going into the castings made under specification. Then, if the heat exceeds twenty tons, another set of two bars are to be cast for each twenty tons or fraction over, in addition to the two sets above mentioned. If the mixture changes during the heat, another set of bars for each change. All of these bars are to be broken transversely, and one bar from each set cast must fulfil the conditions. Tensile tests, though not recommended, may be made from the broken pieces of the arbitration bars, but the cost of turning these test pieces down to 0.798 inches d., together with the screw ends for the machine, must be borne by the purchaser.

The mold, which may consist of a piece of 10-inch pipe, properly bored for venting, has another piece of pipe for a cope, which holds the pouring basin and funnel gates. The two patterns of the bar are molded in a vertical position, drawn out, and the mold closed. Then it is dried, and cooled before filling with the metal in question. The patterns are so made that the bottom is rounded, and a taper of 1-16 inch downward provided, so as to make up for the strain of pouring. Even the facing is provided for, being sand with bituminous facing 12 to 1, all molding sand being put through a No. 8 sieve before using.

The speed of testing is given at a deflection of 0.10 inch in thirty seconds.

Finally, it may be added that as we learn more of the characteristics of cast iron, we may be able to improve the methods of testing it, but it is pretty safe to say that in this country, at least, the producer of the castings will be the one who, by his ceaseless struggle for advancement in product, attains this desired end.

DISCUSSION.

Mr. G. H. Clamer:—The placement of test bars, and the casting of same under the proper conditions to actually represent the casting to be tested, is of vital importance. Not only does this apply to cast iron, but also to bronzes and all alloys subject to segregation. Some of the specifications in this respect are sadly deficient, because of the fact that no stipulation is made as to the manner of attaching test bars, etc. I have in mind more particularly the Government specifications, which read: "The bar to be of certain dimensions and that it be attached to the casting it is to represent." It is entirely at the discretion of the manufacturer where this bar is to be placed, and those who have become familiar with the methods of obtaining the best results invariably place the bar at the bottom, and attach the same longitudinally to the casting. A bar placed in this position represents the skin, the densest and strongest part of the solidified alloy. A test bar taken from the center of the same casting would not show within 50 per cent. to 75 per cent. of the strength of such a bar. Then again, should the bar be attached to the casting perpendicularly at precisely the same place as the longitudinal bar, it will exhibit greatly diminished strength. Such a bar acts as an individual casting simply with a large gate, and if the bar is of sufficient cross-section, a segregated center portion will manifest itself, which causes its weakness. A bar attached longitudinally is devoid of this, whereas on the other hand, a bar cut from the center of the casting is cut from the segregated portion of the same, which portion is greater the greater the thickness of the casting. In a general way, I believe this is also true of cast iron, and as has been shown by Prof. A. E. Outerbridge, one of our fellow members, by tests he made some years ago. Prof. Outerbridge cast a cube of cast iron 12 inches in diameter, and cut the same into 144 one-inch square bars, the bars on the outside of the casting being very materially stronger than those in the center. The bars from the center also exhibiting an open and segregated fracture.

It has been stated by eminent authority, the only way to get a test bar to properly represent the casting, is to make a test bar the full thickness of the heaviest part of the casting.

There is a great deal of truth in this, but as this is of course impractical in all but small work, the next best thing to do is to have a standard practice. The Committee of Cast Iron of the American Association for Testing Materials, of which Dr. Moldenke is a very active member, have adopted for this reason certain standard practice as regards the dimensions, methods of casting and testing of cast iron test bars, which has been so ably discussed by Dr. Moldenke this evening.

Dr. Moldenke:—The question of test lugs or test bars attached to castings is very old and still stubbornly adhered to by many purchasers, notably the Government. Mr. Clamer's argument is a very able one against the practice, and he is perfectly correct in condemning it by implication. What good is a bar attached to a casting if it will give different results when placed in different positions? The founder will always place it where the best results are obtained, but what of the iron in the casting where it does not get as good a chance? For this reason the attached test bar was ignored by the Committee formulating standard specifications, and the good American idea adopted, whereby the metal is given a perfectly fair chance to exhibit its characteristics, and no more. The attention of founder and purchaser may now be directed, not to scheming how to get good results in the bars, but good foundry practice is getting out the castings sound and strong in every part.

Mr. Paul Kreuzpointner:—I agree with every word Dr. Moldenke has said in his valuable paper. For the reasons stated a round test bar is more uniform throughout its section than a square bar and therefore more reliable as a criterion of the quality of the iron it represents. One of the questions not yet settled in the minds of some people is, whether the test bar, is cast separate and distinct from the object which it is to represent, really shows the same qualities as the casting.

It would seem as if the test bar, when molded and cast close to the casting, we would get a more representative test bar.

In this connection I take the liberty to say that for twenty years I have opposed the tensile test of cast iron. In cast iron the elastic limit and the point of rupture are so close together, if not identical, that there is hardly any flow, and the least eccentricity in gripping arrangement will make the test piece break before flow sets in, if there is any flow, and thus we get a fictitious value. The transverse test is a much more reliable test, giving the metal a chance to show what it is. I have had tensile test pieces of cast iron prepared in all manner of forms and have always been convinced that this method of testing cast iron is a delusion and a snare.

Dr. Moldenke:—The fact that a separately-cast test bar rarely represents the qualities of a casting is not so much due to the pouring of the metal into separate molds, but to the difference in the section and proportion of skin to interior, between casting and test bar. As a matter of fact, the attached test bar shows just as wide differences in quality, and also for the reasons just given. Founders, therefore, are relying on the separate test bar results for their own information, whatever they are asked to do for their customer's work. The attached test bar is found practically only in Government work, and in some shops where large cylinders and marine work is cast. It will undoubtedly disappear altogether some day. I heartily agree with Mr. Kreuzpointer anent the tensile test.

Several incidental comments that have been made in the course of this discussion involve the much mooted presence of oxygen, in form of a dissolved oxide of iron, oxide of manganese, etc., in the metal in quetsion. In my opinion this is the solution of apparent contradictions met with when using good irons and getting poor results and vice versa. When it is considered that the presence of several hundreths of one per cent. of oxygen dissolved in a bath of iron will make it unfit for use where even the ordinary strengths are required, it will be readily seen that we have a lot to learn here yet. Unfortunately we have no good chemical methods for the detection of oxygen in iron. Anyone who does much work with the white irons can, however, easily see this matter for himself. Take a heavily burned heat, and shot some of it for laboratory use. On solution in the usual nitric-hydrochloric-sulphuric acid mixture, the iron will dissolve, leaving floating particles of $Fe_3\ O_4$, which may be filtered off and weighed. In fact, unless this this is watched, this iron oxide may be weighed with the silica and reported as silicon, as I have often seen in check analyses which did not agree, until corrected for this point.

Now, if so little oxide of iron can make or unmake a pig iron, there is little wonder why irons of identical composition, but made from different ores, and possibly in more or less good ways, may show different characteristics, when put into castings. It is to be hoped that our experimenting metallurgists will give this point more attention than they do.

Mr. F. T. Wright, referring to the test bars proposed in the "Standard Specifications" for gray-iron castings, suggested that a much more convenient and less cumbersome flask can be made from a six-inch pipe than from a ten-inch one.

Dr. Moldenke:—The selection of the flask by the committee on standard specifications was simply for the guidance of those who wanted to go to the least expense in the matter. Hence a piece of pipe was selected. Where these tests are made regularly, it is highly advisable to have special iron flasks of proper size and shape, to give greatest ease in manipulation.

Mr. Arthur Falkenau:—As tensile tests of cast-iron are considered unreliable, I would like to ask Dr. Moldenke whether he has made any extensive series of experiments, comparing the transverse tests with tensile tests.

Dr. Moldenke:—Many experiments have been made comparing the tensile with the transverse test for cast iron. I made a lot of them myself with a view of testing the current belief that multiplying the transverse test by ten gives the result of the tensile test. Where the inch-square bar is broken transversely on supports 12 inches apart, the result approximates the tensile strength of the iron pretty nearly, and for practical purposes this will do, especially when a good factor of safety is used. However, it must also be remembered that cast iron stands in no comparison with steel, so far as tests go, as the former has no homogeniety, while the latter is very much so. It is the object of the standard tests prescribed for cast iron to minimize as much as possible the effect of the lack of homogeneity of this metal, even if it does seem like hair splitting to some of us.

Mr. Wright inquired about certain experiments which he understood Dr. Moldenke had made with titanium in cast iron, and intimated that he and others present would be interested in hearing the results of these experiments.

Mr. Wm. B. Read, Jr.:—On the strength of Dr. Moldenke's article on Fe Ti as a deoxidizing agent, we made several experiments, with the following results: Taking the first tap from the cupola, which was quite hot, we ran this down to a ladle placed on a pair of scales and poured into it 1200 lbs of metal. This we caught up with a second crane and ran it back up the shop to where the mould was. Before pouring we put in the Fe Ti, which came in the form of a thermite. We fastened the can containing the thermite powder on a long rod and poked it into the molten iron and stirred it vigorously. The can melted and the powder floated to the top with no appreciable result. With so much time the metal had lost its heat and was not of a sufficient temperature to start the reaction. Needless to say, we got no good results from the experiment.

On a second trial, however, we have a different tale to tell. Getting the iron *very* hot we guessed at the amount needed, and without the loss of any time we stuck the can of thermite into the ladle and stirred as before. This time just as the powder commenced to float a violent reaction set about with an almost incandescant lustre. The metal boiled violently and seemed to be raised considerably in temperature. Moreover, a great deal of slag seemed to come to the top. From this mixture we poured a second test (the first being poured from a hand ladle during the first test). The bars were poured on end, about 1½ inches in diameter. These two bars were turned down and pulled, the one before treatment showing 23,700 tensile, the one after showing 28400 tensile. Taking a test from the casting itself, which was a small boring head, we got 33,800 tensile. There was enough Ti added to give .20, but in the chemical analysis no trace of Ti could be found. The chemical analysis of the test showed Si 1.632, Comb. C .87, P .225, Sul .042, Mn .369.

Dr. Moldenke:—The experiments made with titanium were to see what action this metal had on the strength of cast iron. Different proportions from 1 to 4 per cent. were added in the shape of ferro-titanium, and tests bars cast and broken. The results all showed marked improvement in strength, and in every case the titanium had burned out of the metal, going into the slag. The reason seemed to lie in the removal of oxygen, and perhaps other gases from solution in the iron, thus leaving the crystals cleaner and more adhering. Too little work was as yet done along this line of removal of the gases in solution and combination with iron, to say exactly what happens, and it is hoped that we may hear more of this later on.

The use of thermite has a further advantage. Thermite is a mixture of aluminum powder with oxide of titanium. The burning of the aluminum, combining with the oxygen of the titanium, releases the latter and free titanium enters the melted iron, there doing its work of purification.) This further advantage is in serving as a means of introducing other metls into iron. Thus, nickel, which has a very high melting point, is difficult to get into combination with cast iron, the melting point of which is much lower than that of steel, where nickel is easily absorbed. Thermite, this time composed of aluminum powder, and oxide of nickel, instead of oxide of titanium, is an excellent medium for the introduction of nickel into cast iron. The principal use of this grade of cast iron is for chemical pans, etc., where ordinary cast iron will not last.

THE "CRITICAL POINT."

The critical point is that temperature above which no pressure short of "infinity" can reduce any given substance from the gaseous to the liquid condition. The critical temperature of carbon dioxide is 32.5 deg. C. Below its critical temperature, pressure can reduce the particular substance from gas (or vapor) to liquid. Thus Faraday succeeded with ammonia, sulphur dioxide, etc.; but he failed with hydrogen, oxygen, nitrogen, and carbon monoxide because he worked under conditions above their respective critical temperatures.

COMPOUND GAS ENGINE.

According to the *Iron Age*, a compound gas engine has been built with two high-pressure cylinders and a single low-pressure cylinder between them. The high-pressure cylinders work on the Otto cycle, the engine receiving one impulse from them each revolution. The exhaust from the two explosions is expanded in the low-pressure cylinder, the crank of which is 180 deg. behind the high-pressure cranks. Thus, at every forward stroke the low-pressure cylinder takes the exhaust gases from one of the high-pressure cylinders. The total effect is thus to produce an impulse every half revolution. With a 12 horse-power engine 13 brake-horse-power were obtained with the low-pressure cylinder in use, and only 8.9 horse-power without it, 46.2 per cent. being thus added to the power by the use of the low-pressure cylinder and without the expenditure of any additional fuel.—*Iron and Ore Supplies.*

Mechanical and Engineering Section.

(Read by Title.)

The Mississippi: Controlling Floods, Navigation Improvements.

By H. Van Meerten, Member of the Institute.

[Continuation of discussion—Haupt—Van Meerten]

I beg to recall to the readers of this *Journal* that, in the October number of 1903, there appeared an able article from Prof. Lewis M. Haupt, bearing the title "Controlling the Floods of the Mississippi;" that in a letter which was published in the May number, 1904, I expressed my sympathy for the greater part of the measures proposed by Prof. Haupt, but strongly objected to one of them, namely, that of creating outlets. I fully agreed with him in recommending greater discharge capacity by removing bends, by stopping levee construction and heightening, but in that one point only I dissented from his propositions, namely, that of creating and maintaining outlets.

In his answer to my remarks, I perceive that he quite misunderstood me, and I endeavored to correct his views in a later communication. I afterwards tried to explain how the Netherlands' Waterstaat practically carried out their prevailing ideas, and showed how perniciously outlets had interfered with the regular regime of the lower Rhine, Meuse and Scheldt; how inundations were not prevented, and how sedimentation of several reaches was the result.

All this, however, has a somewhat polemic character; criticism without resulting in building up. It is breaking down without subsequent construction. I will now try to build up, with such materials as are at hand. I regret that I have not more complete data at my disposal. Therefore when, in the following, I propose a scheme for improving the "Father of Waters," it is with the strict reservation that I hold myself not responsible for errors eventually committed in the estimation of quantities, as my premises are not complete, and it is, therefore, not impossible that I may err. Nevertheless, I believe that I am not very far astray; but in all cases I can explain the principles of the proposed works.

Let me say at once that, according to the principles which have guided the Danube Engineers, the Waterstaat Engineers and the Tyne and Clyde Commissioners, I should propose for the Mississippi:

1st. That it should have one continuous road-bed gradually increasing in capacity from source to mouth; its capacity being in proportion to the waters carried downward, and insuring as much as possible a current of uniform speed.

2d. That it should have a well defined summer and winter bed, both unencumbered by dykes (levees), buildings, brick-kilns, &c.; only against extraordinary floods, and exceptionally, should dykes be resorted to; ordinary winter floods must have a free, unobstructed passage into the sea.

3d. The regulating of the river, the impounding of its road-bed, where it is too broad, should be effected not by dykes, but by cribs at regular distances. The portion cut off of the roadbed will silt up, and the river creates its own roadbed. An additional advantage of this mode of operation is the land reclamation which will follow, but this is of secondary importance only.

4th. The straightening of the river-bed, preferably by crib-work, but if this should be found to work too slowly, by excavating and dredging.

According to the observations of Capt. James Eads, the discharge of water at the mouth of the South Pass was, in 1875, 1,614 cubic meters per second. According to Mr. E. L. Corthell, formerly Chief Assistant Engineer, South Pass Jetty Works, the South Pass discharged only 0.12 of the whole mass of water carried by the Mississippi. Accordingly the undivided river shoals carry 13,450 cubic meters per second. According to Prof. Haupt, the discharge in flood time exceeds 28,315 cubic meters, or about 2.25 times the mean discharge. At a distance of about 750 m. above the head of the passes, the river has a breadth of 2,450 m., with a mean depth below mean high water, or average flood-tide, of 6.876 m. The profile of discharge measures, therefore, $2,450 \times 6.876\text{m.} = 168,329.7\text{m}^2$. The mean velocity of the current should, accordingly, be almost exactly 0.8 m. per second, or rather more than 1.55 knots per hour in ordinary times, which is rather too stiff for navigation. Lowering this velocity would be advantageous, if it be sustained below and above, otherwise there will be sedimentation and erosion where they are not wanted. Tides oscillate at the rate of 0.56 m. at the mouth, but however slight the oscillation, it must be taken into account.

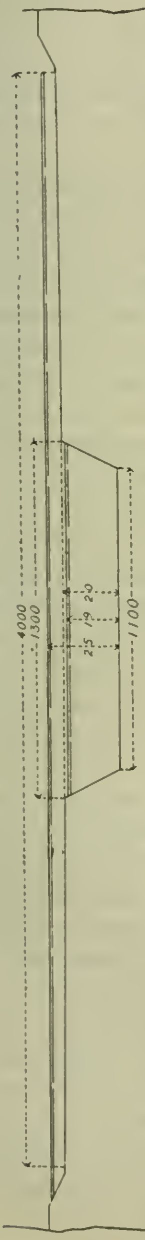

Fig 1

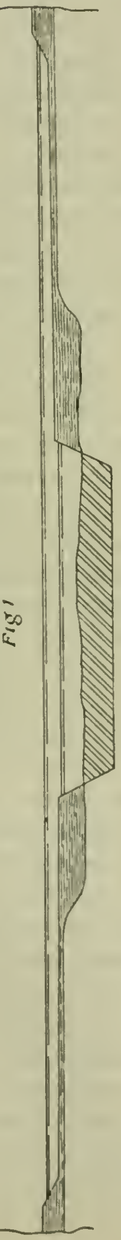

Fig 2

These are the scant premises at my disposal. However scant, they are sufficient to explain the measures which I am about to propose.

The main roadbed of the Mississippi should consist of a summer bed with lateral berms, which, with the summer bed, constitute the winter, or flood bed. These berms should be sacred ground. Under penalty, it should be forbidden to create dykes, to build houses, brick kilns, pavilions, or anything else which may retard the current in winter time. As for ditches and culverts to drain the land in summer, there is no objection. Cultivation in the summer time at the risk of the harvest being lost by premature floods, may be allowed; but no summer quays should be built to protect the crops against inundation.

At the head of the passes the summer bed should have a breadth at the bottom of 1,100 m., at the top of 1,300 m.; the slopes are then not too steep and can be reckoned upon. The top of the bed should be above the bottom 20 m.; 1 m. below this should be ordinary flood level; the depth below flood is accordingly 19 m.; a splendid waterway for the greatest ocean steamers. The winter bed at this station should have a width of 4,000 m.

From the above point the winter bed should increase to 5,000 m. and the summer bed to 1,500 m. at the landsend or mouth of the river. Figure 1 shows the bounds of the proposed summer and winter beds in profile. Figure 2 shows the proposed profile of the river, 750 m. above the head of the passes. The vertical scale is ten times greater than the horizontal one, to get a clearer view of the depth of the channel, which, if the same scale were retained for vertical and horizontal measures, would become microscopically small.

The available profile below average flood level measures 22,705 m^2., the 13.450 m^3. water which need to be discharged per second will flow with a mean velocity of 0.5836 m. per second, equal to 1.134 knots per hour; which is well within the limits necessary for easy navigation. According to Prony's formula, this calls for a fall of 0.000067408, or 1 in 14,835. The distance of the point chosen to the mouth of the river is 20 km. The total fall between these two points will be, therefore, 1.35 m. From Capt. Eads's data I infer that from the latter point the current still is perceptibly about 12 km. in the gulf, where it is zero.

Suppose the mean fall between the mouth and the zero point to be half of what it is above, a supposition which cannot be far from reality; flood level at the mouth of the river must be about 0.4 m. above flood level in the sea. The total fall from the point considered will be 1.75 m.

Suppose the waters to have risen 7 m. above ordinary flood level, a rise problematically large. It is better, however, to err on the side of safety.

Let us see what will then be the regime of the river at 750 m. above the head of the passes. The fall will be 0.0003375, or 1 in 2,963, velocity of current, 3.53 m. per second, or 6.864 knots per hour. The available profile 48,391 sq. m.; the flow of water 14.355 cubic m. per second, which is ten times more than the average. The fall between the point chosen and the mouth of the passes will be 6.75 m., and from this to the sea level 2 m.

The reader will infer from these data that in supposing a rise of 7 m., somehing impossible has been expected. I allow that if really the sea did not rise above ordinary flood level, the supposition of a rise of 7 m. above ordinary flood level at the head of the passes would be ridiculous. But according to Prof. Haupt the level of the gulf has been seen to rise 16 ft., or about

5 m. above flood level; and if such a rise is taken into account, then the supposition of a rise of 7 m. at the head of the passes is perhaps not on the safe side. Let us see whether it is or not.

With a rise of 5 m. in the Gulf, the total available head will be 3.75 m., with a rise of 7 m. above ordinary flood level at head of passes. At the mouth there will be still 1.467 m. above the sea level. The fall will be 0.000114, which is equal to a velocity of 2.022 m. per second, or 3.93 knots an hour; the discharge will be 8,220.6 cubic m. per second, or more than six times the average; or 2.9 times the discharge which Prof. Haupt relates as being still below the actual discharge met in flood time.

Well, it may actually be much more, and the proposed flood-bed would still be of sufficient capacity to discharge the floods of the "Father of Waters" against a rise of 5 m. above ordinary flood level in the Gulf.

Under the most adverse circumstances the proposed flood-bed will be able to confront a rise of 5 m. of the Gulf.

Another question will be, whether the proposed section be not rather extravagant; whether a more modest one will not answer the case. As for that I beg to say that I should not like to propose one inch less breadth of winter bed. The proportion of about 1:3 between summer and winter beds, is one which experience has proved to be a convenient one for European rivers, and, taking into consideration the great relief that the berms afford in flood time, I should not like to embark in a proposition of curtailing in this direction. But; as in the following, the reader will be aware that a gradual regulation of the river will be proposed, gradually also its regime will be changed, and in executing the works, it will become clear, whether it will be necessary to base the works upon a flood level of 7 m. above ordinary high water or somewhat lower. Especially a regulation of the river bed with cribs favors a gradual improvement of the regime of the river and leaves the facultative settlement of levels in accordance with the teachings of experience. But it is better to design the works on such a scale that when experience teaches that they have been designed with too liberal an allowance—with too great a factor of safety—curtailing them is not only quite possible, but easy, by stopping work. If, on the other side, it should prove that the winter flood-bed as projected, is too narrow, the work already started must be removed and replaced by others. It is better to design the works on a grand style, lest no deceptions or disappointments intervene and shake public confidence.

Perhaps there will be those who contend that the proposed system involves a great waste of land. The berms represent a precious capital of arable land, which it is forbidden to protect against floods, which are systematically withdrawn from cultivation, at least during a considerable portion of the year; and when cultivated, the crop is in jeopardy of being inundated by every unexpected flood. True; but in the same way it may be told that the system of introducing factors of safety is wasteful. A screwshaft at regular work is much too heavy for its duty; much material is wasted in its construction; but let a gale disturb the surface of the ocean, let the screw race and turn with tremendous velocity, at once afterwards be deeply immersed again, striking the water with a velocity and a *vis-viva* several times greater than under ordinary circumstances. Then, I think, no one will say it is wasting material and cost to construct the shaft with extra strength; then no one will consider it folly to allow for some extra safety under ordinary circumstances. And so I will suppose that in flood time riparian occupants will feel the benefit of these berms. How much they may grumble when the river is calm, and does not show any tendency to rise; how much they may scold at the waste of land and at the tyranny of the river improvement authorities, who don't allow even the building of a summer quay to protect a valuable crop against inundation; but the great interests which are at stake, the immense benefit which the existence of the said berms afford, make their systematic maintenance peremptory, however much the people may be inclined to transgress regulations in their behalf.

I am speaking from experience. I know that in flood time everyone only thinks, and very naturally so, of his own interests, disregarding those of others and the public. By this individual policy the evil is aggravated; the less the stream is encumbered in flood time by quays, dams, buildings, dykes, the freer its roadbed, the easier the waters find their way into the sea, and the less will be the loss of valuable property.

If these berms are maintained as rigorously as the law permits, the reader may be assured that a caving in, as Figure 2 on page 250 of vol. CLVI (this Journal) shows, or a crevasse as that on Bayou Lafourche in 1903. shown in figure 4, page 254 of the same volume, will be things of the past.

When working out the proposals for improvement of the Mississippi, I was struck with the splendid materials at hand, and astonished how little profit is gleaned from them. A waterway of 1,300 m. in width and with depth of 19 m. under ordinary conditions is available, and what is realized? A channel of only 600 feet or 183 m. in width, silting up at the rate of 5 inches of 0.127 m. a year. Will the opening of the Southwest Pass remedy the evil? I am sure not. After some time it will silt up, just the same as the South Pass, if the *whole* mass of the Mississippi waters is not forced to take its way through the pass, and if outlets are not closed.

In my former article, relating to the opening of the "Oude Maasje," the reader has been made aware how pernicious the influence has been of the Heerewaardensche outlets on the reach Heerewaarden-Loevestein of the river Waal, how this silted up, and how continuous dredging was necessary. Is it not logical to suppose that the silting up of the South Pass is attributable to the same causes? Is it not rational to suppose that the numerous outlets above the head of the passes divert the waters into other channels and deaden the stream in the principal one, which *inevitably* must silt up.

I now ask the reader to follow me in the details of the proposed works. Figure 3 is a sketch showing in what way I would regulate the river at 750 m. above the head of the passes. The profile of the river being known to me, I chose it for this purpose. The river has here a breadth of 2,450 m.; it needs to be broadened into a winter bed of 4,000 m. and narrowed into a summer bed of 1,300 m. I have no information at hand about the shores of the river, but am rather confident that they are either flat or very gently sloping. Cribs of a length of 575 m. at both shores, constructed of fascines, or mattress-work, should be sunk to impound the summer bed. Layer after layer should be sunk, the crib gradually heightened to flood level, and the scouring of the river bed will gradually go on until at length the desired depth has been attained. The river will silt up between the cribs and create its own shore; that is to say, its summer shore. The lengthening of the cribs into the inside and heightening them to above inundation level, will allow the rived to create its own winter shore. At the risk of becoming tedious, I once more repeat that the thus-created summer shore and winter bed must not be interfered with by constructions; dykes, dams, walls, houses, pavilions, brick kilns, &c., should not be allowed to be erected here. Cultivation of cereals should be allowed, when they can be harvested within a six-month, but no cultivation of trees, hedges or plantations should be permitted; ditching, however, should not be forbidden. The river's winter bed should remain a passage as free as possible for expected and unexpected floods.

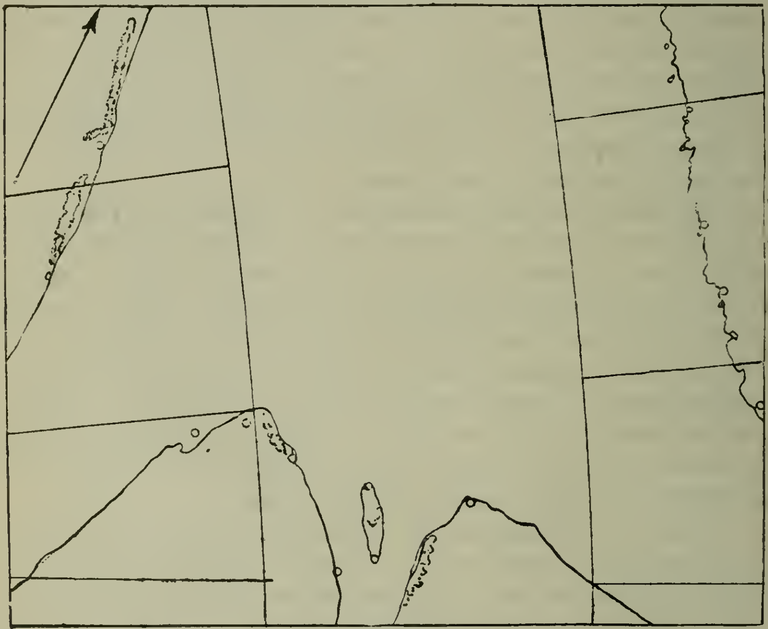

Figure 3.

What is beyond flood bed should be beyond the control of the River Regulation Board; but within, this Board should have supreme power. No other authority should be tolerated; its power should be dictatorial.

In figure 4 are sketched the proposed roadbeds in summer and in winter time, from Quarantine, above Forts St. Philip and Jackson to the mouth. By a series of cribs at a mutual distance of about 1 km., the river is supposed to create its own shores. The cribs are shown in their full ends, and probably along this reach they would require to be executed so; but in the upper reaches, probably they will not need to be laid out in their full length; on the contrary, excavation must be resorted to, to create the summer bed. Where the banks are high and cave, as shown by Prof. Haupt's figure 2 above referred to, the berms will protect the lands beyond the river bed. The more I consider Prof. Haupt's figure 5, representing the lower Yazoo and upper Tensas Levee districts, the greater is my surprise that it should be possible to so neglect a river as is here shown to be the case. A river so neglected must inevitably cause floods and inundations. A bed so tortuous cannot be an outlet for flood water; with such a bed floods are invited. I am the more struck with the configuration of the river in this

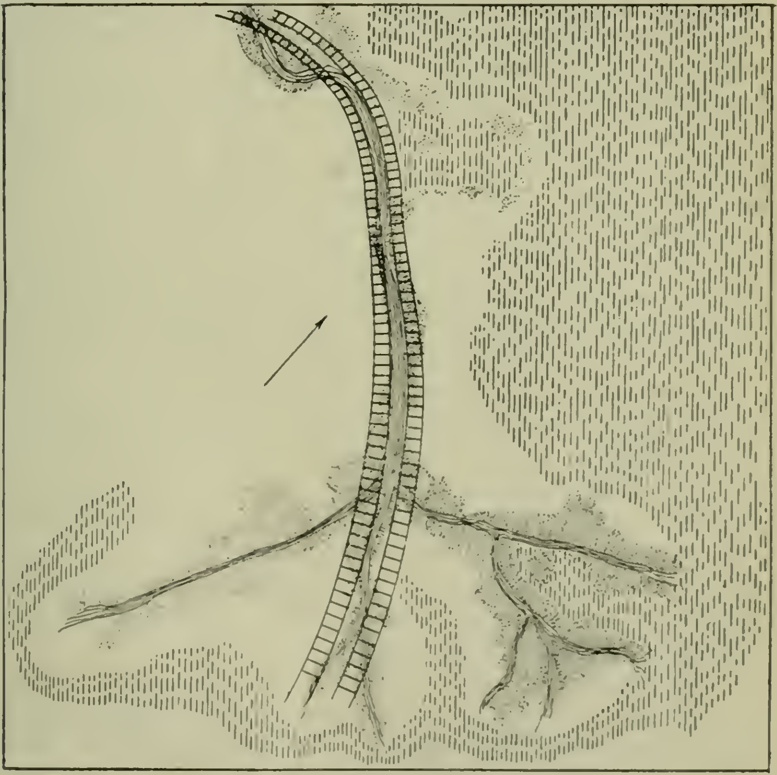

Figure 4.

reach, as its general direction is straight, or almost straight, and its capricious meanderings are wound up, so to say, along this line.

I now beg the reader's attention for the succession in which the work should be carried into existence. Let us start from the principle that every particle of water excepting those which are lost by evaporation, must pass the mouth of the river. Every improvement in the upper reaches can only afford local relief, even provoke calamities in lower reaches, which is not the case with improvements in the mouth of the river; the relief is not only local but must extend to far above. I beg to call attention to a fact, which is probably not known in American circles. Perhaps many will remember that years ago Hungary was much harassed by floods of the Theiss and other tributaries of the Donau (or Danube). It was in consequence of a fault of the Hungarian engineers, after consulting some Waterstaat engineers, for the improvement of this river, that they started its regulation and straightening of its course in the upper regions. Flood water obtained a free passage in these reaches but was afterwards terribly congested in the lower ones; disastrous floods, much heavier than in former times, destroyed much valuable property. The upper Theiss was relieved, but the lower Theiss had to bear the burden of the business. On the contrary, had the regulation been started at the lower Theiss, the greatest relief would have been felt in the lower basin, but the upper basin would also have participated in the relief, although in a less degree.

Therefore, if the improvement of the Mississippi basin is seriously taken in hand, let the work be started in creating a good, roomy outlet into the sea. The work should be started by gradually sinking layer for layer the dams which shall close the Southwest Pass and the Pass á Loutre. Gradually the waters will be diverted from these passes into the South Pass. Gradually the lateral passes will silt up, and the central or South Pass will scour into a wide, deep channel. When these dams are in progress the sinking of the cribs above and below should be started; when these are in progress the following cribs should be started in turn. The Jump and Cubit crevasse should also gradually be closed. The inevitable scouring of the lower reaches will assist the works at the mouth by the greater capacity of water, which will widen the South Pass. Gradually the work should be started higher up; the bends straightened; the summer and winter beds delineated by the cribs; gradually the river will create its own roadbed. When a tributary is met, the works should go on upon the main river as well as upon the tributary. Dykes, or levees, which stand in the way should inexorably be removed; the wasted land be expropriated for the public welfare; every impediment against a free flow of the river removed.

In this way, and only in this way, I am sure that calamities, such as those related by Prof. Haupt, will be things of the past, just the same as they are in the Netherlands. In this way the Mississippi will become and remain one of the most splendid waterways of the world; a navigable channel of 1,100 m. in width at the bottom with 19 m. depth of water. Even Liverpool would envy such a highway into the sea. And I have not a shadow of a doubt that this is not an illusion, but can readily be realized by the engineering profession as soon as they will adopt the right measures and continue steadfastly in this course undiscouraged by apparent minor failures, and trusting to time to perfect what cannot be realized at once.

In the above I did not discuss the question of bar formation at the mouth, and the means to be used to prevent it. It was not without intention that I avoided its discussion, as I am sure that Capt. Eads said the last word there is to say about it; and I believe experience has verified his theory. There is one thing, however, which I cannot leave without discussion. That is the "Sea-wall theory," which Prof. Haupt once more promulgates in his paper on the "Floods of the Mississippi." I had thought that after Eads's able expostulation against it, no one would advert to it again. I do not know how I can better exhibit its incongruity than by quoting Eads's words:

"It is a popular fallacy to imagine that the Gulf presents a barrier to the onward flow of the stream at the mouth of the pass. On reflection it must seem reasonable that a river should flow with less friction between walls of water than between walls of earth. At the bar, the river has its banks of earth no longer, but it still flows between banks of salt water, and over a bottom of brine instead of mud. It has no longer a descent of a few inches to the mile, (In this I disagree with the writer.—v. M.) however, and hence must maintain its current in the Gulf simply by momentum. Friction on its sides and bottom finally brings it to rest; but while its momentum lasts, the widening out into the sea and the final obliteration of the river will proceed very gradually."

With one exception only, which is immaterial to the case, I fully agree with this celebrated engineer's opinion.There is and there must be a fall, a slight one, it is true, but there must be some fall; as long as there is a current there is a fall. If Capt. Eads's theory were true, there should be a sudden fall of velocity in the current just when the water passes the limits of the river. As ahead of them the particles of water move by momentum and fall together and exactly below only by momentum, there should also be a sudden change from fall to no fall, from an inclined surface to a horizontal one. Neither of these propositions is the case. In reality the level of the water, as it emerges from the river channel into the sea, is somewhat above the sea level, and this difference in level gradually dies out and becomes zero where the velocity reaches zero. The difference, though imperceptible in ordinary times, I have often observed in flood time.

I beg to refer further to the theory of the "Surfaces de niveau," but as the matter is irrelevant to the question, it is unnecessary to spend more time upon it. I am sure it was a slip of the pen of the eminent engineer, and pass it over. I can only say that I not only fully endorse his theory, but that I have had occasion, not once but a hundred times, to observe the facts corroborating his theory. Especially in flood time, when the rivers carry a brown-colored sediment, the current is distinctly marked far into the sea; a sharp boundary of river and sea water is so perceptible as not to be mistaken. I have so often passed this boundary, either for business or for pleasure, that I cannot fully confirm the truth of the Captain's words. Let me add that those who adhere to the sea-wall theory confound the case of the starting of the stream into the sea and the case of the permanent condition. When there is a permanent flow, such a wall does not exist and cannot exist. When there is acceleration of current the sea will act as a movable barrier at the stage where the velocity is zero. This point must be advanced further into sea, and as long as the acceleration lasts, the fall between the land's end and the zero point will increase till the flow has become permanent; it will decrease as soon as the rush of water from above diminishes; then the sea water will force the zero point again inward.

In general, therefore, in ordinary times, when the current is permanent, or when the river is gradually rising or falling, obstruction by a sea wall does not exist. But the question changes its aspect with such cases as Prof. Haupt mentions, as for instance, when in 1860, the river near New Orleans rose 1.40 m. within two hours. In such cases the sea wall must act as a retarder; water not in motion must be put into motion, and this can only be done by an increase of the head of water. I beg, however, to refer to what I have already urged: That the works should be planned with a great margin of safety, determined by consideration of observed facts, and their construction should not be discouraged when the results are not directly those which are expected.

In 1876, the following sums were voted for levees:

Louisiana	$1,800,000
Arkansas	1,250,000
Mississippi	447,000
Missouri	500,000
Tennessee	100,000
Illinois	75,000
Total	$4,172,000

To control the floods of the Mississippi, a superficial study of Prof. Haupt's article I think will have convinced his readers that this great sum has been wasted, as the floods have not at all been controlled, and I cordially agree with the learned Professor, that it is high time to stop levee construction and levee heightening, as they can only afford temporary relief. The levee plan may be resorted to, and then with great caution in such cases, but the works must decidedly have a temporary character, such as that of the "Zomerkaden," (Sommerquays), as they are called in Holland. But still better is it to create a condition where there will be no occasion for them; and such a condition is aimed at in my above proposals.

In another grave point, however, I quite disagree with

Prof. Haupt and Mr. James A. Seddon, C.E., namely, that of the systematic creation of outlets. I will not need, however, to expand on this point. I have shown how perniciously they have operated in the Netherlands; I have pointed out that the laming of the South Pass is to be attributed to the curtailing the mass of water which takes its way through it, and therefore insist as strongly as the lessons of theory and practice can insist on the need of creating a river of sufficient capacity to carry its own waters. That is, in my opinion, the rational, and the only rational method to improve a river; it is operating in grand style; it leaves to the river the business of creating its own bed; there is harmony between aim and measures; when the principle is steadily adhered to, there cannot be a doubt that the aim will be attained, though it may be only after long, patient and expensive labor.

On another point I am happy once more to agree with Prof. Haupt. That of taking away of bends, which create great congestion of flood water.

In the above I have freely exposed my views, even against professional authority of the highest character, and hope only that the reader will make serious allowance for any awkwardness of language, by taking into consideration the fact that I am a stranger to his language, and have not within a quarter of a century visited any English-speaking country, and therefore cannot command the true idiom, and that he will be convinced that only my interest in the great river, and the people who have an interest in it, has inspired me with the necessary courage to embark in a discussion under such unfavorable circumstances; to set forth and maintain views contrary to those of authorities so able as the author of the article "Controlling the Floods of the Mississippi River."

Before concluding I beg to call attention to one circumstance. When arranging the works as proposed, every dollar expended will afford relief, locally and generally. The improvement is not bound to time, whether the Government shall expend one or two millions a year. Relief will follow, of course, with a more liberal allowance much sooner, but there is no fear that by progressing slowly, relief must await the completion of the works before it will ensue. No! Every layer of a crib will provoke improvement, if the above sketched program is followed.

In the above I have refrained from considering the financial question, and for cause. I have not, and cannot have, the least idea of the cost of works, when not even a general scheme can be fixed for want of plans, &c. The only plans at my disposal relate to the reach below Quarantine point, and that was sufficient merely to illustrate in a sketch my propositions. But although the proposed system is simplicity itself, I have not a shadow of a doubt that it will involve great cost, and that even with great activity a century will barely be sufficient for carrying them out. But a great river like the Mississippi is worth its nursing, and a great nation like the United States of America is worthy the task of nursing a great river in its bosom.

Buitenzorg, Java, July 8th, 1904.

A SIXTH SATELLITE OF JUPITER.

A telegram has been received at the Harvard College Observatory from Prof. W. W. Campbell, at Lick Observatory, stating that a sixth satellite of Jupiter, suspected by Perrine in December, was discovered by him January 4th, 1905. The position with respect to Jupiter from previous plates taken in January, is as follows: Position angle 269 deg., distance 45. The distance is decreasing 45 sec. daily. The apparent motion is retrograde and the magnitude 14. Derived from observations with the Crossly reflector on December 3, 8, 9, 10, and January 2, 3, 4.

CLOCK ACTUATED BY RADIUM.

A clock which will run for two thousand years has been invented by Richard Strutt, son of Lord Rayleigh. The motive power is a small piece of gold-leaf which is electrified by means of a very small quantity of radium salt. It bends away from the metal substance and keeps moving under this influence until it touches the side of the containing vessel. At the moment of contact it loses its electrical charge and then springs back and is again electrified, and the process repeated. Sir William Ramsay considers that this may be made into a very reliable time-piece at an expense of about $1000.—*Scientific American.*

DETERMINING A SHIP'S BEARING BY WIRELESS TELEGRAPHY.

A Boston inventor has devised a means for determining the bearings of navigable vessels under all conditions of weather, the object being to provide improved indicating devices for use with a ship's compass and the usual sailing-charts. whereby the bearings of known objects at a distance from the ship may be positively determined at times when owing to fog or storm the landmarks may be invisible.

The invention is based upon the scientific fact that "Hertzian-wave" impulses or signals may be conveyed over long distances without connecting-wires. This principle is utilized to determine the position of the ship with relation to known landmarks, thus rendering navigation safer and avoiding delays in the movement of vessels caused by foggy or stormy weather when the usual sight observations cannot be taken.

The apparatus. carried on the ship. is applied to or connected with the binnacle, which incloses the ship's compass; and it consists. primarily, of a receiving instrument electrically connected with an upright conductor so shielded that it can receive only the wave, impulse, or signal (coming from a transmitting station on shore or from another ship or light-ship) through a lateral opening or slot when such exposure is in proper range radially with said ship or shore station. The conductor is surrounded by a rotatable shield, cap, or tube slotted vertically to admit the wave or impulse from a given station at such time only, in its rotation, as the slot or opening is approximately between said station and the inclosed conductor. With this apparatus or its equivalent when used on shipboard a rotatable pointer is employed extending over and close to the compass, always in the same radial vertical plane as the slot or exposure, to indicate on the face of the compass the bearing of the station from which emanates the signal or impulse reaching the receiving instrument through such slot or exposure.

With this system of taking bearings each lighthouse and prominent landmark will have a distinctive name or number by which it is known and designated on sailing-charts, and each will be provided with a transmitting instrument adapted to continually repeat its name or number or to automatically transmit such impulse, wave, or signal as shall make the identity of the station certain. Then when a ship appears off the coast provided with the receiver and compass attachments, the elevated conductor receives through the slot of its rotating and intermittingly-acting shield the impluse sent seaward from the transmitting stations, and the navigator notes at once on his chart the bearing of the station as denoted on his compass-dial by the indicating pointer. From another shore-station he receives a different signal, and by the cross-bearings thus received he obtains his reckoning, showing exactly where on the chart his ship should be. A transmitting instrument on the ship will at such times be able to communicate with the shore-station, thus making its presence and its exact location known.—*Scientific American.*

STEEL CARS AND SAFE TRAVEL.

If, as the records of the Interstate Commerce Commission show, the majority of the injuries and fatalities on our railroads are due to collisions and derailments; and if, as unfortunately seems to be the case, the management of our railroads is unable to reduce the number of accidents of this kind; in other words, if derailments and collisions are, under existing conditions, an inevitable feature of modern railroading—then perhaps the best thing we can do is to render our rolling stock, and particularly our passenger cars, as collision-proof as possible.

The steel car is collision-proof.

A few years ago a certain company began to build steel freight cars; and, of course, the first of these that were sent out upon the road were not long in running into a smash-up. Here they demonstrated, at once, their ability to stand an amount of pounding, crushing, and wrenching which would reduce a wooden car to the proverbial kindling wood. After such a collision, what was left of the wooden cars was burnt on the spot; but the steel cars were unearthed from the wreckage of their older and frailer brothers; their trucks were replaced beneath them; and they were hauled off to the car shops to have the kinks taken out of them.

In a heavy collision, it is the telescoping of one car into another that kills and wounds the passengers; but steel cars cannot telescope. Even with the momentum of a heavy train behind it, the platform of the telescoping car is unable to shear its way through the vertical steel posts (angle irons channels, or T-irons) which form the frame of the car body. Following the line of least resistance, steel cars, in such collision, will slide past each other, or be slewed around and rolled to the side of the track. In this case the injuries to the passengers will be only such as are due to their being thrown violently around, and will generally be limited to cuts and bruises. The all-steel cars of the New York Subway, and the composite cars with steel under-frames, have probably already saved more lives and limbs of the public than the operating company would care to admit. Had the collisions which have already occurred taken place between wooden cars of the old type, the casualty list would have been very much longer.

The Interstate Commerce Commission has accomplished a splendid work in enforcing automatic couplings and the application of the air brake. It may be too early yet, but the time is surely coming when the same Commission will urge or enforce upon our railroads the use of steel cars. For obvious reasons such a great and expensive change could only be brought about gradually; but it will surely come, probably by the voluntary act of the railroads, and as the result of a growing appreciation of the safety and ultimate economy of this durable form of construction.—*Scientific American.*

India, which at one time produced all the diamonds in the world, now produces less in an entire year than are recovered at the De Beers mines, in the Transvaal, in one hour. The present garnet production of India has four times the value of its diamond crop.

PURE NICKEL FOR COINAGE.

Mr. Albert Ladd Colby, a well-known metallurgical expert, recently published an interesting communication on the use of pure metallic nickel for coinage, which, among other useful suggestions, contained the following:

"The advantages of using pure metallic nickel for coins, instead of alloys of copper and nickel, such, for instance, as are now used in coining the United States 5-cent piece, known as our 'nickel,' may be briefly summarized as follows:

"1. Greater resistance of the nickel coin to wear, so that the imprint lasts much longer than the alloy coins.

"2. Maintenance of their bright, attractive color and appearance, in comparison with the objectionable change of color occurring in time in alloy coins containing much copper.

"3. Increased scrap value of the pure nickel coins when finally taken out of circulation over the scrap value of an alloy coin.

"4. Extreme difficulty in counterfeiting, as the more powerful presses and machinery necessary to make a nickel coin than required for an alloy coin render secrecy in counterfeiting pure nickel coins practically impossible.

"5. To the above may be added the fact that if alloy counterfeiting was attempted on account of the advantages of lighter presses, the counterfeit coin could be at once detected from the pure nickel coin from the fact that it is not attracted by a magnet, as is the case with pure nickel."—*Eng. and Mining Journal.*

HARDWOOD SUPPLIES IN THE UNITED STATES.

The greatest area of hardwood forest and the largest supply of hardwoods in the United States are in the region comprising the Southern Appalachian Mountains and the country lying between them and the Mississippi River. For the last two or three years the Bureau of Forestry has been carefully studying this region, which is rich in commercial species, especially yellow poplar, white, red, black, and chestnut oak, chestnut, white pine and hemlock. The field study covered more than four hundred counties, and included all of Tennessee, Kentucky and West Virginia, the extreme western portion of Maryland, the western portion of Virginia, and the two Carolinas, and the northern parts of Georgia and Alabama. For market value and amount of standing timber yellow poplar and white oak are the two most important trees of the region. Poplar attains magnificent size in the coves of the mountain districts and in the rich river valleys of Tennessee and Kentucky. White oak reaches its best development in the river valleys of Tennessee and Kentucky. It is present in very much greater numbers than poplar over the region as a whole, and occasionally forms over 50 per cent. of the stand. Hemlock occurs over a small portion of the region, and white pine over a still smaller part; both confine themselves to the mountainous sections. Chestnut is very abundant.—*N. Y. Evening Post.*

CHEMICAL SECTION

Stated Meeting, held Thursday, February 16, 1905.

The Determination of Sulphur in Iron Ores.

BY J. HOWARD GRAHAM,

Department of Chemistry, Central High School, Philadelphia.

[The purpose of this paper is to determine the influences of ammonium chloride, hydrochloric acid and ferric chloride in solution, on the precipitation of barium sulphate. Is the latter oluble in ferric and aluminum chlorides to the extent that Williams mentions?—THE EDITOR.]

The work presented in the following was not done with a view of publishing a paper, but purely to test statements made by Williams[1] in regards to the enormous loss of S O_3, due to the solubility of barium sulphate in ferric chloride solution, when estimating the sulphuric acid in soils. If he got such low results when determining the sulphur in the presence of small quantities of iron, what losses must be entailed where large amounts of iron are present, such as is the case with iron ores? It was believed that Williams had given due consideration to work done previous to the publishing of his paper, and since ready access to literature on the subject was not the privilege of the present writer, an experimental investigation was started. The data obtained as a result were quite conclusive and satisfactory, so much so, that it was thought worth while publishing them for the benefit of any engaged in work of a similar character.

In estimating the percentage of sulphur trioxide in soils by acidifying and boiling with hydrochloric acid, filtering, precipitating with barium chloride, letting stand a "few hours," and then filtering off the barium sulphate, Williams found that the mean of several results obtained by this method was 0.022 per cent. lower that results obtained by precipitating the sulphur in solution from which all the aluminum and iron had been removed by ammonia. He terms the former the "official" method and the latter the "modified" method. He concludes his paper by stating, "The results point very clearly to the fact that where sulphuric acid is precipitated in the presence of iron and alumina, some of the barium sulphate is dissolved by either the ferric chloride or the aluminum chloride, or both, and that it can only be determined accurately in soil solutions from which these two bases have been eliminated. If the results by the modified method are correct, and it cannot be seen why they are not, then the official method lacks over 35 per cent. of getting out all the sulphur trioxide. In an experiment to test the solubility of barium sulphate in ferric chloride, it was found that when a solution was taken containing 0.110398 gram ferric chloride and 0.001288 gram of sulphuric acid that 17 per cent. of the sulphur trioxide was dissolved, results being obtained in closely agreeing duplicates."

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[1] Amer. Chemical Jour., XXIV, 658.

It could not be credited by the writer that such losses of barium sulphate could obtain in careful work and he believed, before his investigation was begun, that the losses were not due so much to the presence of iron and of aluminum chlorides, but to the excessive use of hydrochloric acid. Then again, by experiment he found that where a moderate quantity of hydrochloric acid even was used, it required more than a "few hours" for the barium sulphate to be completely precipitated. Both the "official" and the "modified" methods had been employed in his laboratory, and no great discrepancies like those indicated by Williams had resulted.

Reviewing the literature on the subject, it is found that extended studies have been made of the "precipitation by barium chloride" method for the determination of sulphuric acid, and of the behavior of barium sulphate when precipitated in the presence of various solutes. It is the purpose of the writer just to make reference to the work done along these lines,[2] and in view of recent investigations, to call attention to the researches of Kuster and Thiel,[3] of Richards and Parker,[4] and of

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[2] Chem. News, XXI, 196; XXIV, 61, 140; XXVII, 13; LX, 19; LXVII, 247; LXX, 181, 212; LXXI, 132; LXXIII, 276.
Jour. Soc. Chem. Ind., 1887, II, 369; 1890, 25.
Zeit. f. Anal. Chem., XIX (1880), 57, 419-431; XXXIII (1894), 208; XXXVIII (1899), 209.

[3] Zeit. f. Anorg. Chem., XIX (1898), 97-103.

[4] Amer. Acad. Sci., XXXI (1896), 67.

Richards[5] himself. None of these investigations just cited, with the exception of that of Fresenius,[6] were carried out along the same lines with the work done in this laboratory, and our results are not of the same character; but they do corroborate statements made by these investigators in the following manner:

(*a*). Barium sulphate is soluble in hydrochloric acid and the proportion in which it is soluble depends upon the amount of hydrochloric present.

(*b*). It is apparently soluble also in very acid ferric chloride solutions.

(*c*). The greater the quantity of hydrochloric present, the longer the time necessary for the precipitation of the barium sulphate.

(*d*). Iron is always precipitated with the barium sulphate, but that this along with some possibly occluded barium chloride,[7] almost balances the amount of barium sulphate soluble in the solution acid with hydrochloric acid.

(*e*). When the iron is precipitated by ammonia, some sulphuric acid remains with the ferric hydroxide.[8]

(*f*). The ignition of the barium sulphate and filter paper together need not be attended by reduction to barium sulphide if done properly.[7]

The present paper presents a resumé of work carried out to ascertain, if possible, the exact influence of ammonium and ferric chlorides and of hydrochloric acid upon the precipitation of barium sulphate while working with iron ore solutions. Fresenius,[9] in a research of similar character, found that in the nascent state, barium sulphate was soluble about as follows:

1 part of barium sulphate in 100,000 parts pure water.
1 " " " " 400,000 " water when barium chloride or sulphuric acid is present.
1 part of barium sulphate in 10,000 parts of 8 per cent. solution of ammonium chloride.
1 part of barium sulphate in 22,000 parts of 2.3 per cent. solution of ammonium chloride.

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[5] Idem. XXXV, 378.

[6] Zeit. f. Anal. Chem., XXXV (1896), 170.

[7] Amer. Acad. Sci., XXXI (1896), 67.

[8] Gladding, Chem. News, LXX, 181.
Lunge. Zeit. Anal. Chem., XIX, 419-431.

[9] Zeit. f. Anal. Chem., XXXV (1896), 170.

1 part of barium sulphate in 22,000 parts of 2.3 per cent. solution of sodium chloride.
1 part of barium sulphate in 7,300 parts of 8 per cent. nitric acid.
1 part of barium sulphate in 7,300 parts of 8 per cent. hydrochloric acid.

Also that in all cases, the presence of barium chloride or sulphuric acid lessens to a great extent the solubility of the barium sulphate.

While Williams confined his attention not to known solutions of sulphuric acid, but to solutions of various samples of soils, it seemed preferable to use a solution of sulphuric acid of known strength and to determine accurately in it, the per cent. of sulphur precipitating in very slightly acid solutions; to check this standardization by neutralizing with ammonia and weighing residue of ammonium sulphate; then to make determinations in the presence of different quantities of ammonium chloride, of hydrochloric acid and of ferric chloride, and subsequently to make determinations of sulphur in iron ores by the "official" and by the "modified" methods, in the former, precipitating the sulphuric acid in the presence of iron and of aluminium chlorides and in the latter, first removing these constituents by ammonia.

SOLUTIONS.

Distilled Water.—Portions of 150 cc. of the same distilled water were used throughout the work; 560 cc. concentrated and examined for sulphur gave 0.5 milligram of barium sulphate, equivalent to about 0.07 milligram of sulphur. The trace was considered negligible.

Sulphuric Acid.—The standard sulphuric acid solution was made of such strength that each 25 cc., representing one gram of ore, would contain approximately 0.1 per cent. of sulphur. It was prepared by diluting 0.264 cc. of sulphuric acid, specific gravity 1.86 with four litres of distilled water.

Hydrochloric Acid.—Acid of specific gravity 1.2 was employed. Ten cc. of this, diluted to 150 cc., and treated with barium chloride, gave no precipitate. However, 100 cc., evaporated almost to dryness in a platinum dish, diluted and treated as before with barium chloride, gave 0.6 milligram of barium sulphate, equivalent to 0.08 milligram of sulphur.

Dilute hydrochloric acid (1 :100) was used as wash water.

Ammonium Chloride.—The "pure" salt used in the analyses was found to contain a trace of sulphur. From ten grams was obtained barium sulphate equivalent to 0.1 milligram of sulphur. In making the solution of 120 grams of the salt in 1200 cc. of water, enough barium chloride was added to entirely precipitate the sulphur, and the solution was permitted to stand a long time and then filtered.

Ferric Chloride.—This solution was made by dissolving 62.4 grams of crystallized Fe_2Cl_6+aqua, in 500 cc. of water, acidulating with 10 cc. of hydrochloric acid, filtering several times and finally diluting to 1000 cc. Fifty cc. were found to contain 0.6028 gram of iron, representing 60.28 per cent. of iron in one gram of ore, the quantity always taken in the routine work for the determinations of sulphur. Two portions of 500 cc. each were examined for sulphur, and the mean of the results in barium sulphate, was equivalent to 0.06 milligram of sulphur.

METHOD AND PRECAUTIONS.

The volume of the precipitating medium was maintained as near 150 cc. as possible. The sulphuric acid and barium chloride solutions were always boiled before adding the latter to the former, and after the addition, the solution was boiled for five minutes and set aside for eighteen hours.

Jena beakers of 400 cc. capacity were used, the high transparency of the glass being a desirable factor in searching all filtrates for traces of barium sulphate. The solutions were repeatedly filtered until clear. At times traces of the precipitate persisted in suspension, but in no case could these have been collected and weighed.

All the barium sulphate precipitates were washed in the filter five times with dilute hydrochloric acid, and afterwards three times with distilled water. All subsequent washings gave negative tests for chlorides.

Great care was taken to prevent reduction to sulphide when igniting the residues of barium sulphate with the filter paper, and at no time upon testing was any trace of sulphide found. The paper was dried, charred very gradually with a small flame, and then the temperature was raised just enough to make the mass glow and burn till no carbon remained, when a blast lamp flame was directed upon it, and the barium sulphate ignited very strongly.

EXPERIMENTAL PART

I.

STANDARDIZATION OF THE SULPHURIC ACID SOLUTION.

(a). Precipitation with Barium Chloride.—In each of the following analyses, the volume of the solution, with the exception of the first three, was 150 cc., and the acidity, five drops of hydrochloric acid.

RESULTS.

$H_2 S O_4$ Solution No. cc. taken	$Ba S O_4$ Found Grams	Sulphur Equivalent Per cent.	Mean of Three Determinations
25	0.0065	0.0893	0.0921
25	0.0069	0.0948	
25	0.0067	0.0921	
50	0.0137	0.0941	0.0953
50	0.0139	0.0955	
50	0.0140	0.0962	
75	0.0209	0.0957	0.0955
75	0.0208	0.0953	
100	0.0279	0.0959	0.0959
100	0.0282	0.0969	
100	0.0276	0.0949	
125	0.0348	0.0957	0.0960
125	0.0351	0.0965	
125	0.0349	0.0959	

All the barium sulphate residues were white. The filtrates from the first three determinations had to be refiltered five times, and the number of necessary refiltrations decreased until the filtrates from the last three came through clear the first time. It appears that the more sulphuric acid there is in solution, the better the barium sulphate filters, and the less tendency it has to cling to the bottom of the beaker. The above differences in per cent. might be due to the small quantities of barium sulphate, which, in spite of the numerous filtrations, escaped in the wash water.

(b). Weighing as Ammonium Sulphate.—To portions of the sulphuric acid solution were added 10 cc. of ammonia, specific gravity 0.9, and the resulting solution was evaporated just to dryness in a platinum dish, on a water-bath within a hood free

from dust and fumes. The weight of the ammonium sulphate, multiplied by the factor 0.24255, gave the weight of sulphur.

RESULTS.

H_2SO_4 Solution No. cc. taken	$(NH_4)_2SO_4$ Found Gram.	Sulphur Equivalent Weight Gram.	Sulphur Per cent.
50	0.0092	0.002231	0.1110
50	0.0092	0.002231	0.1110
75	0.0140	0.003395	0.1131
75	0.0141	0.003419	0.1139
75	0.0140	0.003395	0.1131
100	0.0186	0.004511	0.1128
100	0.0184	0.004502	0.1125
			Mean 0.1125

A correction to this "mean" had to be made for the amount of residue in the distilled water plus ammonia.

This was estimated approximately, by evaporating to dryness 100 cc. of distilled water plus 10 cc. of ammonia. Since all the percentages are based on the fact that 25 cc. represent one gram of material, then the difference between the above "mean" and the one found below, will give a true mean percentage of sulphur in the sulphuric acid solution by this method.

RESULTS.

Distilled Water No. cc. taken	$(NH_4)_2SO_4$ So-called Gram.	Sulphur So-called Gram.	Sulphur So-called Per cent.
100	0.0023	0.05578	0.0139
100	0.0026	0.06306	0.0157
100	0.0025	0.06063	0.0151
		Correction and the mean	0.0149

Estimated "mean" per cent. of sulphur in sulphuric acid solution = 0.1125
Correction = 0.0149

True "mean" per cent. of sulphur in sulphuric acid solution = 0.0976

II.

SULPHUR ESTIMATIONS USING STANDARD SULPHURIC ACID.

(a). Precipitating Medium Contains Ammonium Chloride.—The sulphuric acid was precipitated by barium chloride in the presence of 15, 10 and 5 grams of ammonium chloride (percentages

approximating 10, 6 $\frac{2}{3}$ and $3\frac{1}{3}$) with the addition of five drops of hydrochloric acid.

RESULTS.

H_2SO_4 Solution No. cc. taken	NH_4Cl Present. Grams.	$BaSO_4$ Found Grams.	Sulphur Per cent.
75	15	0.0211	0.0967
50	15	0.0141	0.0969
25	15	0.0070	0.0962
75	10	0.0210	0.0962
50	10	0.0137	0.0941
25	10	0.0071	0.0976
75	5	0.0207	0.0949
50	5	0.0140	0.0962
25	5	0.0071	0.0976

It would appear from the above figures that low results in percentage of sulphur cannot be attributed to the presence of ammonium chloride. If this salt has any influence at all, it promotes the precipitation by causing the barium sulphate to take a granular form, much more so, in fact, than in all other cases; and therefore to filter quickly and clear.

(b). Precipitating Medium Contains Definite Quantities of Hydrochloric Acid.—In the following estimations of sulphur, the same approximate percentages as under (a), of hydrochloric acid (specific gravity 1.2) were used.

RESULTS.

H_2SO_4 Solution No. cc. taken	HCl Present. cc.	$BaSO_4$ Found Gram.	Sulphur Equivalent Per cent.
75	15	0.0206	0.0944
50	15	0.0127	0.0873
25	15	0.0035	0.0481
75	10	0.0207	0.0948
50	10	0.0132	0.0907
25	10	0.0051	0.0701
75	5	0.0206	0.0944
50	5	0.0130	0.0893
25	5	0.0067	0.0921

It appears from the results just obtained, that the precipitation of the barium sulphate is retarded, and the fault seems to lie with the hydrochloric acid. But it is not evident that loss of barium sulphate depends entirely upon the amount of hydrochloric acid present, for we notice that the greater the quantity of sulphuric acid present, along with the same proportions of hydrochloric acid, the nearer the results approach to what they should be. Fresenius[10] also, found that sulphuric acid and barium chloride being present, the solubility of barium sulphate is lessened to a great extent. In the presence of larger amounts of hydrochloric acid, the barium sulphate filtered clear and quickly, which was not the case where smaller quantities were present, the precipitate, besides, clinging very firmly to the bottom of the beaker.

Observing that hydrochloric acid had such a solvent effect upon the precipitate, the question was raised as to whether the results in the first standardization of the sulphuric acid (a) might not have been low, since as much as five drops of hydrochloric acid had been used. To make sure of this, the following five analyses were made, using but one drop of acid.

RESULTS.

$H_2 S O_4$ Solution No. cc. taken	$Ba S O_4$ Found Gram.	Sulphur Equivalent Gram.	Sulphur Per Cent.
125	0.0352	0.004840	0.0968
100	0.0284	0.003905	0.0976
75	0.0213	0.002928	0.0976
50	0.0139	0.001911	0.0955
25	0.0071	0.000976	0.0976

With but a single exception, these results are higher than the highest of those in the first standardization of the sulphuric acid (a), and approach closely to the mean of those in (b). The low result in 4 is accounted for by a considerable loss of barium sulphate in the filtrate. An objection to the use of such a small quantity of hydrochloric acid is, that the barium sulphate is precipitated in a very finely divided state, making it difficult to filter.

(c). Precipitation in the Presence of Ferric Chloride.—Fifty cc. of the ferric chloride solution were used each time, and therefore 0.6028 gram of iron was present, and each 50 cc. already contained 0.5 cc. of free hydrochloric acid.

For trial tests, 75, 50 and 25 cc. portions of the sulphuric acid solution were analyzed for sulphur with 0.6028 gram of iron present in each, and 5 drops additional of hydrochloric acid. The estimations could not be carried out, because on boiling a film of iron salt (?) was precipitated and clung to the bottom of the beaker. As a second attempt, to 25 cc. of the standard solution, was added 1 cc. of hydrochloric acid, and to another 25 cc. portion was added 3 cc. of acid, but upon boiling a similar scale came down in each, though in less quantity. However, with 5 cc. of acid present (that is a total of 5.5 cc.) the scale did not appear, and the following three determinations were made.

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[10] Zeit. f. Anal. Chem., XXXV (1896), 170.

RESULTS.

H_2SO_4 Solution No. cc. taken	Iron Present Gram.	H Cl Present cc.	Ba S O_4 Found Gram.	Sulphur Per cent.
25	0.6028	5	0.0076	0.104
50	0.6028	5	0.0142	0.097
75	0.6028	5	0.0217	0.099

All the barium sulphate residues contained few specks of iron oxide, but were not colored uniformly with it. After the three above determinations, the following five were made.

RESULTS.

H_2SO_4 taken cc.	Iron Present Gram.	H Cl Present cc.	Ba S O_4 Found Gram.	Sulphur Per cent.
75	0.6028	10	0.0219	0.100
50	0.6028	10	0.0150	0.103
25	0.6028	10	0.0079	0.108
25	0.6028	10	0.0077	0.105
25	0.6028	10	0.0078	0.107
	Mean of the foregoing eight determinations			0.103

This result must be corrected, since 50 cc. of the ferric chloride solution contained about 0.005 per cent. of sulphur. Thus corrected, it would read 0.098 per cent. instead of 0.103 per cent.

The barium sulphate filtered clear and the ignited residues were practically white. It will be noticed that in the set of three determinations, 5 cc. of hydrochloric acid were used, while in the set of 5, 10 cc. were used, and yet there was no corresponding loss of barium sulphate. From the results, it would appear that neither the ferric chloride nor the hydroloric acid, together, have the solvent action upon barium sulphate attributed to them; but again it is quite evident from the results under 2 (b), that the acid alone does affect the precipitation, some loss of barium sulphate always being incurred. And it must be remembered, that the amount of acid present in the above cases is just sufficient to prevent the precipitation of the iron scale. The exact conditions in the last series of five determinations were: 150 cc. of solution containing 0.6028 gram of iron and 10.5 cc. of hydrochloric acid. The following experiments with iron ores themselves will enlighten us still further.

III.

SULPHUR ESTIMATIONS USING IRON ORES.

Samples of one gram each of ore, were treated separately with hydrochloric acid, a small quantity of nitric acid and a few crystals of chlorate of potash, and, after oxidation and evaporation, the residues were treated with hydrochloric acid and evaporated to dryness twice. To each, 10 cc. of hydrochloric acid were then added, the chloride of iron dissolved, and the solutions diluted. One of these was treated with ammonium hydrate to remove all iron and aluminium, filtered, and the filtrate just made acid with hydrochloric acid, and the sulphuric acid precipitated with barium chloride. The other solution was filtered, diluted and precipitated with barium chloride in the presence of iron and aluminium. The first method may be called the "modified method," according to Williams, and the other the "regular," or, as he names it, the "official method."

RESULTS.

	Percentages of Sulphur in Ores	
	Modified Method	Regular Method
1	0.1471	0.1677
2	0.1485	0.1650
3	0.1210	0.1512
4	0.0880	0.0948
5	0.0687	0.0783
6	0.1512	0.1677
7	0.0866	0.1210
8	0.0742	0.0852
9	0.1058	0.1237
10	0.0962*	0.1045
11	0.1512	0.1608
12	0.0687	0.0838
13	0.1086	Lost
14	0.1306	0.1590
15	0.1801	0.2177

16	0.1375	0.1333*
17	0.1828	0.1897
18	0.1787	0.1677*
19	0.1471*	0.1691*
20	0.1663	0.1691*
21	0.0948	0.0990*
22	0.0990	0.1120
23	0.0783	0.0783
24	0.0632	0.0673*
25	0.1003	0.1045*
26	0.1320	0.1320

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*Traces in washings.

In the first two estimations, the precipitated hydroxides were filtered with the aid of a filter pump; but since the residues became so dry, and therefore difficult to wash thoroughly, they were subsequently filtered in the ordinary way and afterwards washed five times with distilled water. The low results by the "modified" method, in the first fifteen estimations, could not be accounted for at first; but upon redissolving the hydrated iron and aluminium and treating with barium chloride, noticeable traces of sulphur were found. In the subsequent eleven determinations the hyrdoxides were redissolved, and the occluded sulphur obtained by precipitation was filtered along with the main portion of barium sulphate. From the results, it appears, that the sulphuric acid tends to cling firmly to the precipitated hydroxides, and in appreciable quantities. The use of too much hydrochloric acid accounts for the low result in number nineteen.

The last eleven results in column one will be seen to agree closely with those in column two, except that the per cent. of sulphur is a trifle lower where ammonium chloride and hydrochloride acid are present than is the case with ferric chloride and hydrochloric acid. Similar results were noted in the work with the standard sulphuric acid thus:—

	Per cent. Sulphur
Present, ferric chloride and hydrochloric acid	0.098
" ammonium chloride and hydrochloric acid (5 drops)	0.096
Difference	0.002

The higher results by the "regular" method cannot be due entirely to the presence of iron in the barium sulphate, for although some of the residues had specks of iron oxide in them, there were many others just as white as those obtained by the other method. As it was intended to determine iron in the barium sulphate, all the residues by the regular method had been saved. Of these, mixed thoroughly, 0.1662 gram was fused with sodium carbonate, and the ignited oxides of iron and aluminum obtained weigned 0.0039 gram, so that on the average, in every 0.01 grain of barium sulphate, (= 0.137 per cent. of sulphur), there was but 0.00023 gram of the oxides, making a difference in the per cent. of sulphur of about 0.0003. The slightly higher results, therefore, cannot be due to iron alone, so their explanation must be sought for in another source. It might be that the ferric chloride in some way counteracts the action of the hydrochloric acid, while the ammonium chloride does not.

The foregoing results are sufficiently conclusive to show that barium sulphate is not soluble in ferric chloride, to the extent at least that Williams mentions; rather that this iron salt acts restrainingly upon the act of solution of the barium sulphate in hydrochloric acid until too large quantities of the acid are present. The hydrochloric acid may prefer to form an acid chloride of iron rather than exert its solvent effect upon the barium sulphate, or the ferric chloride may act as does barium chloride and sulphuric acid to mitigate the solubility of the barium sulphate in hydrochloric acid.

In conclusion, we would recommend the method involving the precipitation of the sulphuric acid in the presence of iron and aluminium chlorides. It is the quicker of the two methods mentioned, and fully as accurate. It demands, of course, that the analyst control the quantity of hydrochloric acid he uses, a quantity that need not exceed 10 cc. if but one gram of ore be taken, for the function of the acid is principally to keep the iron in solution. We believe that the information gained in this investigation can be applied to the determination of sulphuric acid in soils as well as in iron ores.

Laboratory of the Spanish-
American Iron Co., Daiquiri, Cuba.

ELECTRIC DISSIPATION OF FOGS.

The dispelling of fogs by means of electric currents is exciting a good deal of interest among leading physicists of the world. It is possible by the use of electricity to rid the city of London or New York harbor or San Francisco harbor or any other neighborhood of the heaviest fog. The only question is the cost. It may be too great, and this is what a commission is trying to ascertain at the instance of the city of London. The report is looked forward to with much interest. Sir Oliver J. Lodge, one of the foremost of British physicists, is giving this subject profound thought, which is itself proof of the importance of the work and of the probability of the successful solution of the problem. His latest patent, just granted, provides for a comparatively simple electrical apparatus, consisting of "a combination of high potential rectifiers arranged in quadrilateral groups of four, or multiples of four in such a way that, instead of the reverse pulses of the alternating current supply being suppressed or nonexistent as at present, they are redressed to form the positive and negative discharging streams required for deposit purposes." In other words, the alternating current is used, but the pulse is all in one direction.

The property of the electric discharge of causing the coalescent deposit of matters suspended in a gaseous medium has not come into general practical use on account of the difficulties attendant on the use of the statical electrical apparatus, this class of apparatus being too delicate and easily upset for use on an extensive scale, to again quote from Sir Oliver's patent papers. There is nothing new in the knowledge of the general principle involved in all fog-dispelling apparatus. The direct current passing through the atmosphere provides, in the form of electrons, the necessary nucleus about which the particles of moisture collect until they constitute drops of rain. To dispel the London fogs, for example the apparatus would be stationed at different points about the city to project their currents through the atmosphere until the fog has precipitated as rain.

Electrical engineers agree that the cost of such operations would probably be great, measured in equipment and maintenance, as well as in horsepower required. It would mean the establishment of large electric power stations. Possibly such stations might dispose of their power to financial advantage during days when their services are not needed for ridding the city of fog. But the cost of alleviating this moisture and hindrance to business would be considerable, no matter how economically the electric plants might be managed. Yet in considering the cost, it must be with relation to the good accomplished in the health and comfort of the community, as well as to business. A London fog costs a good deal of money. So does a fog in such a harbor as New York. It holds up the routine of business, which is expensive. Thus while it might cost a great deal of money, yet compared with the financial saving by preventing the holding up of business, and with the general public benefit, the expense might be relatively small, as is frequently the case in the matter of large public expenditures.—*Scientific American Supplement.*

CALCIUM CARBIDE AS AN EXPLOSIVE.

According to M. P. S. Guédras (*Comptes Rendus, 1904*), calcium carbide is introduced into a metallic cartridge, separated by a diaphragm from the necessary water for its decomposition; the cartridge also contains an air space and a cavity having the detonator. The cartridge is introduced into the bore-hole, which is tamped with a wooden plug, and by striking a projecting rod the diaphragm is pierced. After five minutes the cartridge is exploded by firing the detonator. The rock is shattered, but not projected, and can be easily hewn with a pick. The charge of carbide is 50 grams.

GOLD FROM SEA WATER ONCE MORE.

Sir William Ramsay recently has announced that the old problem of extracting gold profitably from the sea can be successfully solved.

Newspapers of repute have given much space to explanations and interviews thereon, and even the staid *Spectator* devotes two columns to a consideration of its possible success and the effect thereof on the world's economy.

There are some ridiculous calculations based on alleged results. One critic solemnly asserts that 5,000,000,000 tons of solid gold awaits successful prospectors. The bubble has not yet been pricket, though it has been contracted in its dimensions. The weightiest authorities, speaking with gravity and becoming dignity of the exalted promoters, have expressed disbelief in the theory that it will pay to extract the gold.

The syndicate interested in the scheme is said to have employed Sir William Ramsay professionally, but seem to share with him the fear of eventual ridicule, for on a recent exposure they and he alike hastened to make statements "with a view," as they said, "of stopping possible speculative dealings by the public." At that time Sir Wiiliam Ramsay wrote:

"The process is still in an experimental state. Needless to say I do not hold shares in the syndicate."

The inventor of the process by which it is hoped to make a corner in the world's gold is H. J. Snell.

We question very much whether Sir William Ramsay has stated more than the fact that sea water contains a certain percentage of gold, a proposition that no chemist will deny. Probably upon this utterance of Sir William's the London syndicate has built its extravagant claims.—*Scientific American.*

RESISTANCE OF RAILWAY TRAINS.

An author in *Zeit. des Oester. Ing. Ver.* after having reviewed the trials of M. F. Barbier on the Northern Railway of France on the resistance of trains, gives the results of other independent tests of the same kind to secure similar data regarding Austrian rolling stock, says a writer in *Machinery.* The result of these experiments has been presented in the same form as those of Mr. Barbier, and the formula derived is $R = a + bV + cV^2$, in which R is the resistance of the car in kilograms per ton of material, V the speed in kilometers per hour, and a, b, and c constants which are then reduced to a graphic formula where the several factors are set forth.

These tests were not made by means of indicators and dynamometers, but by observing the speeds and accelerations which the vehicles attained upon different grades, a speed that amounted to from 36 to 48 miles an hour, and sometimes held this for a comparatively long time. In the matter of cars at least 323 trains were used whose weight, length and composition were varied to correspond with the condition of actual service.

The author also notes the difference between this method of testing and the dynamometer method, of which he has made no use. He also gives the principal dimensions of the vehicles used and the curves obtained, not only by himself but by Leitzmann, Wittenberg, Clark and others in former researches. Among other formulæ given are $R = 3.8 + 0.025V + 0.001V^2$ (between 24 and 48 miles an hour) for a 4-4-0 compound locomotive weighing 55.6 tons and having a six-wheeled tender weighing 36.7 tons in working order, attached; and $R = 1.6 + 0.184V + 0.00046V^2$ for four-wheeled cars weighing from 11 to 15 tons.

In conclusion, M. Sauzin summarizes the numerous influences which tend to modify the resistances of trains, such as wind, exposed areas, lubrication, temperature, etc.—*Scientific American Supplement.*

CALORIFIC POWER OF LIQUID FUELS.

In a paper recently published in the *Revue Technique*, M. L. Levi makes the following comparison between the calorific values of different fuels used in internal combustion engines:

	B. T. U. per lb.
Methylated alcohol	10,620
Methylated alcohol mixed with 50 per cent. gasoline	14,200
Crude American oil	19,630
Refined American oil	19,880

The mixture of methylated alcohol can, it is stated, be used as easily as ordinary gasoline, but unmixed with gasoline it is necessary to warm up the carbureter a little before starting, as the alcohol does not vaporize readily enough below a temperature of 68 deg. F. As an alternative, gasoline may be used at the start, the alcohol being supplied later. No trouble is found with the admission valves in using alcohol, and if at times there is a deposit of soot or tar, this arises generally from the use of a bad carbureter. A little acetic acid results on combustion, but not enough to cause damage. The carbureter should be of a type which will deal out a measured quantity of the liquid at each suction stroke. The exhaust gases are free from the unpleasant smell prevalent in the case of gasoline motors. The principal objection to the use of spirit lies in cost, which, to compete with gasoline, should be about twenty cents per gallon in place of about twice as much, as is at present the case in France. In Germany the cost of methylated alcohol is only about 18 cents per gallon, so that the alcohol motor is becoming more and more popular there.—*Horseless Age.*

THE FRANKLIN INSTITUTE

Stated Meeting, held Wednesday, January 18, 1905.

A New Form of Diffraction Grating Replica.

By Frederic E. Ives,

Member of the Institute.

[Abstract:—An improved method of making replicas of Rowland Diffraction Gratings. Casts are made from the rulings on speculum metal by covering with solution of soluble gun cotton in amylacetate and allowing same to dry, after which they are stripped off under water, placed face down on plane glass and the water dried out under pressure, leaving the lines as air spaces between film and glass. They are then sealed up under another glass with a balsam mixture, thus protecting them from injury.—The Editor.]

With a Rowland diffraction grating having 15,000 lines to the inch and a Browning Student Spectroscope, every line in the solar spectrum, that was mapped with elaborate care by Kirchhoff with an elaborate and costly prismatic spectroscope, can be clearly seen and the wave-lengths easily measured. The superior efficiency of the diffraction grating for spectrum analysis was first practically realized through the labors of Rowland in perfecting his machine for ruling such gratings at the Johns Hopkins University, and inaugurated a new era in spectroscope work.

Every great university, and many schools and colleges, are now equipped with Rowland gratings, but they are too costly to come into such general use as is desirable, and students are seldom allowed to use them for practice work, because they are so costly and so easily injured.

The desirability of a method of reproducing such gratings at a comparatively low cost has long been recognized, and a partial solution of the problem was realized by Thorpe, of Manchester, by making casts in celluloid, floating them off in water, and putting them down, face up, on plate glass. Such replicas are easily and cheaply made, and are good enough for some purposes, but the celluloid film always distorts sufficiently to mar the definition more or less, so that even the best of them define better over some limited portion of their area than over all They give the best results only when the rays entering the spectroscope are practically parallel, as with direct sunlight without a condenser, and transmitted through a selected portion of the grating. Even then, owing to some scattering of the light, which manifests itself as a pale fringe or halo about the lines in bright-line spectra, the lines of the solar spectrum do not appear as black as with the original Rowland grating. Even if the celluloid film did not stretch, the manner of putting it down on glass would cause the inevitable slight unevenness of thickness not only by refraction to destroy the perfect parallelism of the emerging rays, but would also distort the plane of the diffracting surface, and the difference in refractive index of the celluloid and glass would produce disturbing reflections between the two surfaces of the replica. The defects introduced by any one of these sources of error may be slight, but that altogether they are of very material importance the result always shows.

I have had occasion to make considerable use of Thorpe process grating replicas, and have made them myself very successfully, but the desirability of realizing a more perfect method so impressed itself upon my mind that I have been carrying on systematic experiments for more than a year, with the result that I have worked out and reduced to successful practice a very remarkable improvement upon Thorpe's method.

This improvement is effected (1) by making the casts in a harder and less elastic material than celluloid; by (2) putting them face down upon the glass and forcing them into optical contact therewith, so that the perfect plane of the diffracting surface is preserved, and by (3) sealing them up under another plane glass, with a balsam mixture having the same refractive index as the casting material, so that the perfect parallelism of the transmitted rays is insured, and at the same time the grating is protected from injury.

There is a very small but even shrinkage of the casts, but after measuring up a large number, I found that it never amounted to more than four, or less than two in a thousand, and that by easily established conditions it would be kept very close to either of these figures. Under the conditions finally settled upon, the replicas come out uniformly, almost exactly

15.050 lines to the inch, and with so little distortion than an expert spectroscopist in one of our universities, working with a Hilger spectroscope, which utilized the entire aperture of the replica, declared that he could discover no difference in definition between it and an original quality A Rowland grating. A photograph of the E b region of the solar spectrum made with one of them in a Browning Student Spectroscope shown with good definition every b group line that appears in the Angstrom and Kirchhoff maps, and more than fifty lines between E and b.

The fact that these replicas are good enough for the most serious spectroscopic work, can be made at a comparatively low price, and may be handled freely by students in schools and colleges without risk of injury, leads me to think that the achievement is one of real importance.

THE FRITZ MEDAL AWARDED TO LORD KELVIN.

The first award of the John Fritz Medal, which was established by the professional associates and friends of John Fritz, of Bethlehem, Pa., on August 21, 1902, his eightieth birthday, to perpetuate the memory of his achievements in industrial progress, has been awarded to Lord Kelvin. This award was made by the following board selected for the purpose: From the membership of the American Society of Civil Engineers: Robert Moore, Alfred Noble, Chas Warren Hunt, Chas. Hermany. From the membership of the American Institute of Mining Engineers: E. G. Spilsbury, James Douglas, Charles Kirchhoff, E. E. Olcott. From the membership of the American Society of Mechanical Engineers: John E. Sweet, Robert W. Hunt, Samuel T. Wellman, James M. Dodge. From the membership of the American Institute of Electrical Engineers: Carl Hering, Charles P. Steinmetz, Charles F. Scott, B. J. Arnold. The medal is of gold of the value of about $100, and with it is presented a certificate of the award. The medal was awarded to Lord Kelvin for "Cable Telegraphy and other General Scientific Achievements.—*The Iron Age.*

DETERMINING MOISTURE IN STEAM.

A method of determining the moisture in steam at atmospheric pressure was described by Professor D. S. Jacobus, of Stevens Institute, in a recent paper read before the American Association for the Advancement of Science. A known weight of superheated steam at a given temperature was mingled with a known weight of saturated steam at atmospheric pressure. The steam, after the mixture, was still superheated and its temperature was measured. Careful measurements were made to determine the radiation of the apparatus. From date thus obtained the amount of moisture in the saturated steam was determined. This method, he explained, is similar to that employed by Mr. George H. Barrus in one of the older forms of his calorimeters. The particular problem to be investigated was how much moisture would be contained in steam at atmospheric pressure after it had passed through two separators of a certain form. The tests showed that the steam at atmospheric pressure leaving the separators contained about one-tenth of one per cent. of moisture, a result which was within the probable error of the instrument, for which reason it was fair to conclude that the steam was dry.—*Eng. Record.*

MELTING POINTS.

A. L. Day and E. T. Allen have recently prepared, in the laboratory of the United States Geological Survey, apparatus for generating, regulating and measuring temperatures up to 1600 deg. C., which, according to *Electrochemical Industry* (December, 1904, II, xxi, p. 500), has proven easy of manipulation and very exact. It is in effect a reproduction of the Reichsanstalt temperature scale, the temperature being measured with thermoelements exclusively. The scale is establishd from the melting point of four metals, viz., cadmium, zinc, silver and copper. The melting point of those metals, as determined at Washington and Berlin, are as follows:

Metals	Washington.	Berlin.
Cadmium	321.7 deg. C.	321.7 deg. C.
Zinc	420.0	419.0
Silver	962.2	961.5
Copper in air	1065.3	1064.9
Copper in reducing atmosphere	1083.6	1084.1

These melting points are, therefore, well established for pyrometrical colibrations.

UTILIZATION OF BLAST FURNACE GASES.

At the conclusion of Rossi's article on the utilization of blast furnace gases for the generation of electrical energy, especially in connection with the problems of electric smelting, the author gives a tabulation of the various estimates which have been made by different authors on the energy available from the surplus of blast furnace gases over all requirements of the blast furnace. These estimates vary between 468 and 868 hp. per ton of pig iron made per hour. If all the surplus blast furnace gases in the United States should be utilized there would be available between 1.000,000 and 2.000,000 hp. The figure calculated by the author from Gayley's data in his dry blast run (with only 1,726 pounds of coke per ton of iron) is 724 hp. available per ton made per hour.—*Electrochem. and Met. Ind.*, May.

THE OSMIUM LAMPS.

The "Auer Os," as it is called, from its inventor, Herr Auer von Welsbach (who also invented the mantle of thorium and cerium), is constructed of a filament of metallic osmium. This is a rare element, the first of the heavy-platinoid group, including osmium, iridium and platinum. Osmium as a metal has had, till recently, but little use, except in such restricted ways as the osm-iridium point for gold pens. Of its chemical compounds, the only one that is fairly common is the tetroxide ("4-oxide") OsO_4, or "osmic acid," as it was popularly but inaccurately called; this is used in staining thin sections of organic tissue in microscope work. Some peculiarities of this oxide are, that it is readly formed by heating the metal, that it is volatile, and worst of all that it has occasioned bad accidents to eyesight. The vapor of this tetroxide on touching the cornea of the eye of the careless experimenter is reduced to metallic osmium, which forms an artificial but unremovable "cataract," resulting in a permanent clouding of the sight. On the whole, however, the metal peacefully reposed in the cabinet of chemical curiosities, till it was called upon to furnish a luciferous filament in competition with the ordinary incandescent carbon lamp. At 37 volts, and 1.5 watts per c.p., the filament is 280 mm. long and has a diameter of 0.087 mm.; it thus appears that a pound of osmium can furnish many thousand lamps. The difficulty of making a thin and even thread was overcome by mixing the finely-divided metal with thick paste of some sticky organic compound; this was forced through a die made of diamond or sapphire, emerging as a filament, which was then charred in the steamy reducing atmosphere. Osmium is brittle when cold, but soft when heated. The life of the lamp has frequently extended beyond 5,000 hours. The rival in metallic-filament lamps is that made of tantalum, but both are in the state of promising experimentation. Fritz Blau recently read an authoritative paper on this subject before the Elektro-Technische Verein of Berlin.—*Eng. and Mining Journal.*

THE TANTALUM LAMP.

A life test of tantalum lamps, which has now progressed about 550 hours, has given results that bear out quite fully the statements concerning the lamp made by two engineers on the staff of the Siemens & Halske Company. Two lamps with clear globes have been burning about 550 hours, and they have not fallen off in candle power as yet by 10 per cent. The efficiency is about 1.8 watts per cp. for the clear globe lamp and 2 watts for the frosted globe lamp. The filaments get beady in appearance after about 50 hours, but change very slowly subsequently. Burned in a nearly horizontal position they sag considerably during the first period of their life and then begin to tighten up again. The light has almost exactly the same hue as that of the Nernst lamp. In this test the tantalum lamps have held up better in candle power than an Edison lamp burned and tested with them for a check.—*Elec. World.*

"BEWARE OF THE UNEXPECTED: IT IS THE IMPROBABLE THAT HAPPENS."

This motto used to be printed on the wall of an old New England school of engineering. The converging of varying factors into one definite result, often malignant, sometimes benign, is illustrated in the natural history of accidents. We know of a case where a man fell into one of the large stock-bins at a huge Western smelter, and, owing to prompt action of the foreman, came through with the ore, and came through alive. All engineers of any experience can parallel this with dozens of anecdotes of accident with a fortunate sequel; but of the whole list, few could match—in novelty, at least—the experience of the workman who was recently blown unharmed through the roof of the New York-Brooklyn Subway tunnel by a compressed-air leak, up through the bottom of East River,, in a dramatic geyser of aerated mud and water, to be promptly rescued by a policeman who was at hand as though in waiting. This sounds like a tale of Jules Verne, but it is only a bit of actual commonplace; the humor of it is that it befalls not always the clairvoyant nor the theosophist, but the engineer.—*Eng. and Mining Journal.*

ELECTRIC FURNACE INVENTIONS.

F. J. Tone, of the Carborundum Company, has patented a method of heating carbon articles (brushes, electrodes, etc.), which, like the manufacture of carborundum, belongs to that class of electric resistance furnace methods in which the current is passed along a definite path (the "resistor"), thus localizing the heat. While in the corborundum furnace the charge (which is a non-conductor of electricity) is packed around the carbon resistors, this is not done in the case of carbon articles which are conductors. Mr. Tone arranges them in groups or masses without interposed insulation, and separates them from the resistor by an air space which later on is filled with gaseous products of the driving off of volatile matter. Since there is no direct contact between the resistor and the carbon articles, the heat is conveyed to the latter by convection and radiation.

D. A. Holmes, S. A. Tucker and E. Van Wagenen have patented an arc electrode consisting of zirconium carbide admixed with a suitable binding material, such as coal tar or molasses. The flame arc between two such electrodes is said to give "a light of exceptional brilliance when compared with arc lights of other kinds which are subjected to the same conditions of temperature (or voltage and current)." The zirconium carbide is prepared in an electric furnace from the mineral zircon admixed with an excess of carbon. In this connection it may be mentioned that according to reports from Germany zirconium is the metal of the filament lamp which is about to be placed on the market.

Three patents granted to F. J. Machalske refer to the treatment of phosphate rock. Rock containing tricalcium phosphate is crushed and mixed with sodium chloride and carbon and the mixture is heated in an electric furnace to a temperature sufficient to decompose the rock, and effect the production of phosphoric chloride and calcium and sodium carbides. The phosphoric chloride is treated with water for the production of phosphoric and hydrochloric acid. The calcium-sodium carbides may be treated with water for the production of acetylene, calcium hydroxide and sodium hydroxide. If the above electric furnace process is carried out in an atmosphere of nitrogen the carbides combine with the nitrogen to form cyanamides, which may be treated with water for the production of calcium and sodium carbonates and ammonia, or they may be mixed with sodium carbonate and smelted in an electric furnace for the production of sodium cyanide.—*Elec. World.*

TIN IN DAKOTA.

Among recent discoveries of tin ore is that at Tinton, in Lawrence county, South Dakota, near the Wyoming boundary. The cassiterite is found in a granite rock, which intrudes among mica and hornblende schists; the tin-bearing pegmatite is 245 feet thick, and of this thickness 104 feet is said to contain 0.69 per cent., or, say two-thirds of one per cent. metallic tin. An adit 400 feet long cuts this width of ore at 80 feet below the surface. Open-cuts exhibit an extension of the deposit, and have yielded the material which has been sent to a mill, 3,000 feet from the mine. The mill contains Gates crushers, roughing rolls, finishing rolls, a bucket elevator, spitzkasten, impact screens and Bartlett tables. It was intended to crush dry, but the mica in the ore rendered screening so difficult that wet methods were adopted. The concentrate obtained assayed 63 per cent. tin, and the loss in treatment was nearly 16 per cent. It is expected that total cost of operation with a large mill, would not exceed $2 per ton, but this is on the assumption that a large and continuous supply of ore is forthcoming, which remains to be proved.—*Eng. and Mining Journal.*

STRUCTURE OF STEEL.

When a solvent absorbs a solute, as common salt, there is a wide variation possible in the proportions of the two as long as the temperature is fairly high. But when the mixture freezes, one or the other of the solution-ingredients will separate as it happens to be in excess of the eutectic equilibrium. If a dilute water-solution of salt is cooled, water will separate till the limit is reached marked by 76.4 per cent. of water and 23.6 per cent. of salt. On further cooling this mixture will remain in liquid till minus 22 deg. C., when it will congeal as one physical unit, without separation of either salt or water. This is the *eutectic* of water and salt, containing 23.6 per cent. of the latter. In the case of steel, the assumed eutectic is cementite, Fe_3C. (containing about 6.7 per cent. of carbon).—*Eng. and Mining Journal.*

Correspondence.

Dr. Wm. H. Wahl, Secretary, The Franklin Institute.

Dear Sir:—Enclosed please find a note from Mr. William P. Bancroft, correcting certain statements made by the committee in the obituary notice of the late Mr. William Sellers, in the May *Journal.* I would ask that you give place to Mr. Bancroft's communication in the next issue of the *Journal,* or at all events make the correction that he desires.

Permit me to take advantage of this opportunity to supply one important omission in our memorial, viz.: the fact that William Sellers received the honor of election to membership in the National Academy of Science, in 1873.

Yours truly,

C. Sellers, Jr.

Philadelphia, May 17th, 1905.

Coleman Sellers, Jr.

Dear Friend:—In the article in the *Journal* of the Franklin Institute respecting William Sellers, and elsewhere in print since his death, I noticed the statement that his maternal grandfather, William Poole, came from England to observe a transit of Venus, and remained here. Our common ancestor, William Poole, who, it is understood, took part in an observance of the transit of Venus, was our great-grandfather, not our grandfather, and was not an Englishman, but an American.

Respectfully,

William Poole Bancroft.

Wilmington, Del., 5th-mo. 5th, 1905.

Book Notices.

PUBLICATIONS RECEIVED.

Finnisches Patentgesetz (Patent Laws of Finland), from John Svanljung, Helsingfors.

A Treatise on Gear Wheels, by George B. Grant. Eighth Edition. 1899. Grant Gear Works, Boston, Philadelphia. 8 vo., pp. 103. Numerous illustrations.

Chemical Survey of the Waters of Illinois, Report for the years 1897-1902. By Arthur Wm. Palmer, Sc.D., Prof. of Chemistry, University of Illinois print. From the University.

Catalogue of Machinery and Tools. Brown & Sharpe Mfg. Co., Providence, R. I.

Mineral Resources of the United States. Calendar Year 1903. David T. Day, Chief of Division of Mining and Mineral Resources. Washington, Govt. Print, 1904. From the U. S. Geological Survey. (8 vo., pp. 1204.)

A Primer of Forestry. Part II. Practical Forestry, by Gifford Pinchot.

Bulletin No. 24, Part II. United States Department of Agriculture. Washington, Govt. 1905. 88 pages, illustrations. (12 mo.)

Project for the Panama Canal, by Lindon W. Bates, with general plans and profiles of the waterway, the regulation works and terminal harbors. 4 to., copyright, 1905.

U. S. War Department: Annual Reports for the fiscal year ending June 30, 1904. 4 vols., ill. 8 vo. Washington, Govt., 1904.

Bulletin of the University of Wisconsin, No. 102. An investigation of rotations produced by current from a single-phase alternator, by Arthur Curtis Scott. Madison, University, 1904. (162 pages, ill. 8 vo. Price, 50 cts.

Report of the Commissioner of Education for the year 1903. Vol. 1. Washington, Govt. Printing Office, 1905. (1216 pages. 8 vo.)

The Secret of the Circle and the Square, by J. C. Willmon. (30 p. ill. 12 mo.) Los Angeles, Cal., Author's Edition, 1905.

Illustrated Catalogue of Files and Rasps. 1891. G. & H. Barnett Co., Philadelphia, second edition, 1905. (46 pages, illustrated. 16 mo.)

Iowa State College Engineer Experiment Station. Bulletin No. 9. Notes on steam generation with Iowa coal, by G. W. Bissell. Ames State College, 1904. (16 p., illustrated. 8 vo.)

U. S. Geological Survey. Production of coal in the United States from 1814, the rate of the earliest record, to the close of 1904. Washington, Govt. 1905. Folded sheet.

Anthracite was the coal first mined, and from 1814 to 1821 Pennsylvania was the only producer; in 1822 Virginia began mining, the two States supplying the market until 1828. Kentucky was the next State to become a competitor, and was followed in a short time by Illinois and Ohio. Pennsylvania was again the leader in the bituminous output, which began in 1840, seven other States producing small amounts. The total output of coal in 1814 was 22 tons, from one State, and the greatest yearly output, from twenty-nine Etates, was 357,356 tons in 1903. A. R.

Preliminary Report on the Operations of the Coal-Testing Plant of the United States Geological Survey, at the Louisiana Purchase Exposition, St. Louis, Mo., 1904. Edw. W. Parker, Jos. S. Holmes, Marcus B. Campbell, Committee in charge.

The work of the committee was provided for by an Act of Congress of February 18, 1904. The history of this Act is interesting as showing how futile is an expressed intention of Congress when there is anybody who wishes to change its spirit , if not its letter. The proviso to the bill was "That all testing machinery and all coal and liquids to be tested shall be contributed without charge to the Government." But once this bill was passed there was no trouble in passing "an additional $30,000." The work has been well considered, well carried out, and the results are interesting.

The authors show their familiarity with the project by taking unusual pains to collect fair samples, for, as Huxley said, the mill of mathematics will grind one out material of any degree of communition, but the value of what you get out depends upon the quality of what you put in.

If the authors actually took the pains they describe to secure average samples they deserve very great praise. Sixty-five car loads of samples, from seventeen States, were tested viz.: Alabama, Arkansas, Colorado, Illinois, Indiana, Indian Territory, Iowa, Kansas, Kentucky, Missouri, Montana, New Mexico, North Dakota, Pennsylvania (for comparison), Texas, West Virginia, Wyoming.

There were generally four tests applied, viz.: The steam test, the washing test, the cooking test, the briquetting test and the producer gas test. Pages 32 to 60 contain analyses of the coals with proximate determinations of H, C, N, O, calories, and British thermal units; to which are joined the values of the last two calculated from the ultimate analyses, assuming the combustion of H, C, and S to produce respectively 34460, 8080 and 2250 calories.

So much has been done that it is a pity the item of fuel-ratio or the ratio of fixed carbon to volatile hydro-carbons neglecting the ash was omitted. This is more necessary when comparatively unknown coals are being investigated.

"Owing to the small appropriation"—(only $60,000)—the washery plant was made as small as possible. The washing apparatus consisted of a New Century Jig and a modified Stewart Jig. The moisture was, of course, increased; the ash and sulphur reduced. In one of the coals the amount of good coal in the refuse was found to be 3.5 per cent. of the original charge, or 5.5 per cent. of the *coal* in the original charge. For gas-producer tests a Taylor pressure gas-producer, furnished by R. D. Wood, of Philadelphia, was employed. The coking tests were undertaken in a battery of three bee-hive ovens, from plans furnished by Mr. John Fulton, of Johnstown, Pa. The briquetting tests were made in an English machine (Wm. Johnson and Son, of Leeds), and in an American machine (National Compressed Fuel Co., of Chicago).

A series of tables makes the report very convenient, as it is very instructive. F.

Lecons sur l'Electricité. Professées á l'Institut electro technique Montefiiore annexé a l'Université de Liége. Par Eric Gerard, Directeur de set Institut. Tome premier, etc., avec 400 figures dans le texte. (8vo. pp. xii + 882.) Paris: Gauthiers-Villars, Editeur, 1904.

This elaborate work is devoted to an exposition of the theory of electricity and magnetism, electrical measurements and the theory and construction ofelectrical generators. It embraces the course of instruction followed in the institute named in the title, and gives an idea of the extreme thoroughness of the course of instruction pursued in the institution.

W.

Elements of Glass and Glass Making. A treatise designed for the practical glass maker, comprising facts, figures, receipts and formulas for the manufacture of glass, plain and colored, including an appendix containing useful information pertaining to the subject. By Benjamin F. Biser. Chemically revised by J. A. Koch, Phar. D. (8vo, pp. 174.) Pittsburgh: Glass & Pottery Publishing Co., N. D.

The above-entitled work is announced to have been prepared by a practical glass maker, for many years an active factory manager. It has been compiled for the use of the glass manufacturer. The principal data presented in the book have been culled from the contents of the author's note-book and may accordingly be expected to represent the ripe experiences of years of practice.

The chemical side of the work has been revised by a competent specialist. W.

Die elektrochemische Reduktion der Nitroderivate organischer Verbindungen in experimenteller und thereotischer Beziehung. Von Joh. Moeller. (8vo., pp. 113.) Halle a. S. Verlag von Wilhelm Knapp, 1904. (Price, M. 4.) M. 4.)

The publisher has added to the valuable series of electro-chemical and electro-metallurgical works issued from his press, the above-named volume dealing with certain interesting problems in organic electro-chemistry, a field which has only recently begun to attract much attention. Goeppelsroeder's pioneer work in the branch of dyeing, commenced a quarter of a century ago, for many years afforded the only examples of the attempted application of electro-chemical methods to the industries, but within the past decade the progress in this department has been highly encouraging—as witness the successful commercial production, by electrical methods, of chloral, chloroform, iodoform, vanillin and various products of the coal-tar industry.

The literature of this subject is scattered and difficultly accessible, and the present work, dealing specially with the electro-chemical reduction of the nitro-derivatives of organic compounds, will be cordially welcomed by all investigators in this field. W.

Jahrbuch der Elekrochemie und angewandten physikalischen Chemie. Berichte über die Fortschritte des Jahres, 1903. Herausgegeben von Dr. Heinrich Danneel (unter Mitwirkung von mehreren gelehrten Fachmaenner.) X Jahrgang. 8vo, pp. 930. Halle a. S.: Verlag von Wilhelm Knapp. 1905. (M. 26.)

The tremendous expansion of electro-chemical science and industry in recent years could have no more convincing evidence than this massive volume of nearly 1000 pages, in which are briefly recorded the noteworthy items of scientific and technical progress in this field of activity which were made public during the year 1903.

This year-book, since its first appearance ten years ago, has, with characteristic German thoroughness, given to men of science, engineers, manufacturers and others interested in the subject an admirable "uebersicht" of the entire field—scientific and technical—of electro-chemistry, and it has become simply indispensable to all who wish to keep in touch with it.

W.

Die Galvanoplastik. Von Dr. W. Pfanhauser. (Mit 35 in den Text gedruckten Abbildungen. 8vo, pp. **xi** + 138.) Halle a. S.: Verlag von Wilhelm Knapp, 1904. (Price, 4 marks.)

The art of galvanoplastic reproduction is not carried on in this country to anything like the extent to which it is practiced abroad, especially in France and Germany, where the reproduction not only of coins, medallions and numberless smaller objects of artistic or historic interest is practiced on a great scale, but likewise the copying of objects which would be regarded here as of enormous size. There is, therefore, a considerable field for expansion in this direction awaiting development at the hands of our domestic galvanoplastic operators.

The work above named is a practical handbook which will be found well adapted for the requirements of those interested in this branch of the arts. W.

The Recent Development of Physical Science. By William Cecil Dampier Whetham, M.A., F.R.S., Fellow of Trinity College, Cambridge. (8vo, pp. xii + 344.) Philadelphia: P. Blakiston's Son & Co. 1904. (Price, $2.00.)

In this work the author gives an exposition as free as possible from technical language of some of the most important investigations which are now being carried on in the leading physical laboratories of the world. Those embrace, for example, such topics as the liquefaction of gases and the absolute zero of temperature, fusion and solidification, the problems of solution, the conduction of electricity through gases, radioactivity, atoms and ether, astro-physics, etc.

Official Report upon the Mines, Mining, Metallurgy and Mining Laws, &c., &c., of the Argentine Republic, by H. D. Hoskold, M. and C.E., &c. Buenos Ayres, South America, Bank Note Co., 1904.

This is a well-printed, stiff-paper covered, royal octavo, book of 475 pages, by H. D. Hoskold, Inspector General of Mines of the Argentine Republic and Director of the Government Department of Mines and Geology. It is an unusually successful attempt at English book-making by Latin typos, though frequent instances occur of such errors as only journeymen foreign to the language they are setting up may be excused for making. Although its character is that of a clossified list or description, it badly needs both a table of contents and an alphabetical index. The first chapter of 44 pages contains an interesting compilation of the various histories of the Incas, of Peru, and of the other parts composing Argentina.

The title of the second chapter, "Historical Sketch of Modern Mining," is misleading. What is meant is of more recent mining in Argentina. It takes 22 pages. The third chapter of 34 pages is concerned with the different economic minerals in the Province of La Rioja. This subject is treated very concisely. It might more properly be considered a general description of various minerals and their usual composition. Localities are named very rarely and then almost invariably the statement is queried. For instance, under "Kupfernickel,' the text says it * * * "generally contains the following elements, which are extracted from Bristow's Mineralogy"(!). The tables of percentages from page 91 to the middle of page 95 are somewhat lessened in value from the omission of a statement as to the substances referred to by the percentage values, but tables 47 to 102 the substances referred to by the percentage values, but tables 47 to 102, inclusive, give the constituents, the percentages and the names of the minerals, but as there are frequently very discordant values from the same mines, it would have been better to make the descriptions still more specific.

Chapter IV deals with the mining Province of "La Rioja"; Chapter V with the Copper, Silver and Gold Mines of the Province of the Districts of Mejicana, Ofir, Amapallo and others. Chapter VI, Mines and Mining in the Province Catamarca. Chapter VII, the same in the Province Tucuman; Chapter VIII, Salta; Chapter IX, Jujuy; X, Mendoza; XI, San Juan; XII, San Luis; XIII, Cordoba; XIV, Buenos Ayres; XI, the National Territory of the Andes; XVI, ditto Miseionas; XVII, ditto Central Pampa; XVIII, ditto Neuquen; XIX, ditto Rio Negro; XX, ditto Chubut; XXI, ditto Santa Cruz; XXII, ditto Terre del Fuego; XXIII, Metallurgy in Argentina.

The following is a sketch of the processes for reducing copper ores in the old style furnaces, near Pelican, three leagues southeast of Fuerte del Andalgala. 1st. Calcination of the crude ore; 2. Reduction of a portion of the crude ore to regulus and calcination of the same; 3d. pulverization and calcination of half the regulus obtained from the first reduction; 4th. "*Refundition*" of a portion of the calcined regulus with a part of that not calcined; 5th. Refining Operation. Under the head of Hydro-metallurgy it is stated that low-grade copper ores containing 1½ to 3 per cent. Cu exist all over the district, and the wish is expressed that some cheap process, such as the Clourdet, the Henderson, or the Statberg process might be employed. Chapter XXIV, The Mining Laws of Argentina. Chapter XXV, The Coal Deposits and Geology of the Republic.

In the list of names of those who had contributed to our knowledge of the geology of Argentina it was remarkable that that of Prof. W. B. Scott, of Princeton, was missed. Chapter XXVI, General Observations and Data. Appendix. Catalogue of the official collection of minerals of Argentina mines sent to the St. Louis Exhibition.

The work was originally ordered by the Republic of Argentina for distribution at the Paris World's Exhibition of 1889. Subsequently Dr. Wenceslao Escalante, Minister of Agriculture, Comemrce and Industry, ordered a new work in English for distribution at the St. Louis Exposition.

F.

Committee on Science and the Arts.

(Abstract of Proceedings of the Stated Meetings of Wednesday, April 5th, and May 3d, 1905.)

Dr. Edward Goldsmith in the chair.

The following reports were adopted:

(No. 2335.) *Eastman Co.'s Perfection Fire Nozzle and Fire Hose Support.* Cyrus E. Robinson, Concord, N. H.

This invention, which is covered by several letters patent of the United States, to applicant, consists of a hose-rest and a nozzle attached to a section of hose to which is attached a Siamese connection permitting a supply of water under pressure through one or more hose lines.

The hose rest consists of an iron rod to which is attached an iron "U"-shaped rest for the hose and a similar rest for the nozzle, the latter having in the arms of the rest a spring snap for engaging the lugs of the nozzle in order that the nozzle be held in place. The second "U"-shaped rest is provided with a leather strap so that the hose can be securely strapped to the hose rest. Suitable iron handles connect the two hose rests adapted to be grasped by a fireman in directing the stream. Connected with the rod, by a swing joint, is a second rod, having at its end a three-way prong to prevent slipping on the pavement. This rod is in two pieces, held together by an extension sleeve to permit raising or lowering the hose rest.

The nozzle, or play pipe, consists of two pieces, made of aluminum, for the purpose of reducing the weight of the apparatus, the play pipe being of various sizes, up to three inches or more, if desired. The base of the play pipe contains a cylinder of thin metal concentric with the play pipe and about one-half the diameter of the pipe. The cylinder is held in place by two radial plates at right angles and extending from the inner cylinder to the shell of the play pipe. This arrangement has a decided effect on the stream from the nozzle, holding it together for a great distance from the nozzle and preventing spraying of the stream.

The investigating committee made a number of tests of this apparatus in connection with the High Pressure Pumping Service at Delaware Avenue and Race Streets, Philadelphia. The hose stream showed a very superior delivery of water, though the apparatus could be used only within a very limited radius from a fixed position.

In recognition of the value of the apparatus as a hose-rest for controlling fire streams at high pressures, as well as its value in play pipe service for delivering a solid stream for a considerable distance from the nozzle, the award of the Certificate of Merit is made to the inventor. (*Sub-Committee*, Charles A. Hexamer, Chairman; Wm. McDevitt.)

(No. 2340.) *Color Photographs.* Michael Miley and Henry Mackey Miley, Lexington, Va.

Abstract: In this method of chromo-photography the results are obtained by an application of the principles of the three-color process. The subject is photographed on three separate plates with light filtered through color screens of red, green, and violet, respectively.

From these negatives, photo-prints are made on gelatine pigment paper, such as carbon tissue, the carbon pigment being replaced by pigments of the three primary colors—red, yellow and blue—and the gelatine then sensitized in the usual way by potassium bichromate.

The blue tissue is exposed under the red screen negative; the red tissue under the negative from the green screen. and the yellow tissue under that from the violet screen. The prints are then developed upon celluloid supports by washing out with warm water, as usual.

The resulting pictures are transparent positives in the respective colors, the transparency and depth of color resulting from the graduation in thickness of the developed film of gelatine;; this variation in turn representing the graduations of light and shade of the respective negatives.

These colored diapositives are then transferred from the celluloid supports upon which they have been developed and superposed in proper registry on a suitable piece of gelatine coated with paper, which proves the final support. The red is usually transferred first, the yellow following over the red, and the blue over both, though in some cases the yellow is preferably made to underlie the red. Each film, before the succeeding one is imposed upon it, is followed with a solution of gelatine containing a hardening agent, such as chrome alum. The three films are then securely held together upon their support of white paper and by their combination of the three primary colors in graduations corresponding to those of the respective screen negatives, they present a reproduction of the color effect of the original.

Previous practice in this art in respect, especially, of the use of chemically inert pigments to impart the requisite color to the respective gelatine tissues has been essentially similar to the Miley procedure.

Another method in vogue involves the impregnation of the gelatine tissue with soluble tinctures of the requisite color, such as indigo or eosine, which are retained in the exposed and developed chrome-gelatine film in proportion as it has been rendered insoluble by the action of light.

Another method is to dye the three diapositives with tinctures which are absorbed by the gelatine in proportions corresponding to the carying thickness of the films as left by the development.

Another modification is to produce the first color picture directly on the paper by printing and toning, usually, in blue, and then using only the red and yellow diapositives in superposition on the blue print.

The report sets forth that the distinctive feature of the Miley process consists in the method of imparting the requisite color to the respective tissues of gelatine, which he effects by the use of finely-ground pigments of red, yellow and blue, of a spectroscopic color value equal to, or approximating, the color value of the corresponding primary in the original subject. These are incorporated with the gelatine solution by intimate mixture, substantially in the manner in which carbon is incorporated with the gelatine solution in making tissue for carbon prints; the prime requisite in both cases being that the pigment should be inert—chemically—as regards both the gelatine and the chromic sensitizer. The novelty of the Miley process appears, from the report, to consist in the method of developing the prints, and transferring them, after development, to their permanent support.

The report concludes with the statement that the details of the process have been thoroughly worked out and fully described in the patent specification. (See U. S. Patent, No. 711,875, October 21st, 1902.)

In view of the excellent results of which this process is capable—as evidenced by the specimens submitted for examination, the award of the Edward Longstreth Medal of Merit is made to the inventors. (*Sub-Committee*, Louis E. Levy, Chairman; Samuel Sartain, Daniel Baker.)

(No. 2352.) *The Phonosphere.* The Phonosphere Mfg. Co., New York.

Abstract: This invention, which is the subject of U. S. letetrs patent Nos. 685,024, Oct. 22, 1901; 692,409, Feb'y 4, 1902; and 717,311, Dec. 30, 1902, to John E. Alexander, is an improved form of talking machine and record blanks for the same. The record blank consists of a spherical disk (*i. e.*, one in which the record surface is part of the convex surface of a sphere) of 10 inch radius, the limiting boundary of the surface being a circle.

The disk is mounted at one end of a shaft, which is rotated by means of a friction wheel, the edge of which works upon a second spherical driving disk concentric with the record disk. The mechanical arrangement is such that the shaft supporting and rotating the record disk is gradually brought from an inclined to a vertical position, thus enabling a stationary stylus to engrave a continuous record in a spiral path, passing from the periphery towards the center. This spiral is again traced in transmitting the record thus produced.

The report comments as follows upon this combination: The form of the record tends to secure freedom from warping and gives a large superficial area for reproduction. This large area permits a high rate of speed of rotation, thus increasing the amplitude of the vibrations, and, consequently, the volume of the sound. The mechanism secures a uniform length at all parts of the record for the same time.

The stylus arm is stationary and the requisite pressure upon the stylus is light, thus tending to reduce the wearing upon both stylus and record.

These improvements are recognized by the award to the inventor of the Edward Longstreth Medal of Merit. (*Sub-Committee*, Geo. A. Hoadley, Chairman; Wm. O. Griggs, T. Carpenter Smith, Thomas Spencer.
Chairman; Wm. O. Griggs, T. Carpenter Smith, Thomas Spencer, L. F. Rondinella.

(No. 2355.) *Metallic Railway Tie.* Richard Raby, York, Pa.

(An advisory report.)

(No. 2358.) *Colt Automatic Pistol.* The Colt's Patent Firearms Mfg. Co., Hartford, Conn.

Abstract: This invention is the subject of the following letters patent of the United States, Nos. 580,924,5,6, April 20, 1897; 708,794, Sept. 2, 1902, and 747,585, Dec. 22, 1903, granted to John M. Browning, of Ogden, Utah, and is manufactured by the applicant.

In its fundamental features of design, the Colt Automatic Pistol closely resembles the modern magazine military rifle. The breech block consists of a bolt sliding parallel to the axis of the barrel. The cartridges are spring-fed through a suitable opening underneath the frame and are pushed into place by the closing of the breech. The empty shell is ejected in substantially the same manner and by devices now long in use in self-ejecting rifles, by the rearward movement of the block. After the first cartridge has been fired, the breech automatically opens by the reaction of the firing impulse, ejects the empty shell and closes by the pressure of a reaction spring, inserting a fresh cartridge ready for firing at the will of the operator. The latter feature is provided for by a device that prevents the release of the hammer until the trigger is freed and again pulled. Without this device, it is noted in the report, the action would become automatic, uncontrollable and far too rapid.

An elaborate mechanical description of the invention follows, which would be unintelligible without the aid of illustrations. The report concludes as follows: "The conclusion of the sub-committee is, on the one hand, that the inventor has devised a safe, powerful and serviceable arm of simple design, and on the other, that the manufacturers, in the commercial production of an arm whose component parts are radically different from those of the same class previously manufactured, have displayed commendable skill in manufacturing engineering."

The report, in conclusion, recommends the award of the John Scott Legacy Premium and Medal to John M. Browning, the inventor, and of the Edward Longstreth Medal of Merit to the Colts' Patent Fire Arms Mfg. Co. (*Sub-Committee*, Lucien Picolet, Chairman; J. M. Emanuel, Wm. O. Griggs, W. J. Williams, F. Lynwood Garrison.)

The following reports passed first reading:

(No. 2213.) *The Hill Torch and Tracer.* John B. Semple, Pittsburgh, Pa.

(No. 2216.) *The Nernst Lamp.* The Nernst Lamp Co., Pittsburgh, Pa.

(No. 2338.) *Electrolytic Interrupter for Induction Coils.* Dr. A. Wehnelt, Charlottenburg, Berlin, Germany.

(No. 2357.) *Photo-Printing Machine.* L. F. Rondinella, Philadelphia.

WM. H. WAHL,
Secretary.

Sections.

MINING AND METALLURGICAL SECTION. *Stated Meeting*, held Thursday, February 2d, 8 P.M., Mr. G. H. Clamer in the chair. Present, 45 members and visitors.

The following officers were elected to serve for the year 1905: President, Mr. G. H. Clamer; Vice-Presidents, Prof. A. E. Outerbridge, Jr., and Mr. James Christie; Secretary, Dr. Geo. P. Scholl; Conservator, Dr. W. H. Wahl.

The President introduced the speaker of the evening, Dr. Richard Moldenke, Secretary to the American Foundrymen's Association, who read a paper on "The Testing of Cast Iron." The paper called forth a lengthy discussion, participated in by Messrs. Paul Kreuzpointner, Altoona, Pa.; G. H. Clamer, H. S. Haldeman, Arthur Falkenau and several visitors. The paper, with discussion, will appear in the *Journal* in due course.

The Chairman expressed the thanks of the meeting to those who had participated in the evening's event, and the session was adjourned.

WM. H. WAHL,
Secretary pro tem.

Stated meeting, held Thursday, March 9, 8 P.M. Mr. G. H. Calmer in the chair. Present, 27 members and visitors.

The President introduced Mr. Spurr, of the U. S. Geological Survey, Washington, D. C., who read a paper describing the geological and topographical features of the Tonopah Mining District in Western Nevada. The speaker illustrated his remarks with the aid of a number of lantern slides. The subject was discussed by the chairman, Dr. H. Chance, Dr. E. Goldsmith and the author. A vote of thanks was extended to Mr. Spurr for his admirable communication.

In the absence of the author, a paper by Dr. N. S. Keith on "New Methods in the Metallurgical Treatment of Copper Ores," was read by the Secretary. A brief discussion followed.

Both papers are referred to the Committee on Publications.

GEORGE P. SCHOLL, *Secretary.*

Stated meeting, held Thursday, April 20th, 8 P.M. Mr. G. H. Clamer, President, in the chair.

Present, 14 members and visitors.

The paper of the evening was read by Dr. George P. Scholl, on "Modern Improvements and Tendencies in the Metallurgy of Gold." Some discussion followed and the meeting was adjourned.

G. P. SCHOLL, *Secretary.*

MECHANICAL AND ENGINEERING SECTION. Stated Meeting, held Thursday, April 13, 8 P.M., Mr. John C. Trautwine, Jr., in the chair.

Present, 38 members and visitors.

The chairman introduced Mr. Kenneth Allen, Superintendent of the Water Department of Atlantic City, N. J., who read a carefully-prepared paper on "The Sanitary Protection of Public Water Supplies." The paper was freely discussed by the chairman, Drs. Henry Leffmann and W. J. Williams, and the author.

The chairman extended the thanks of the meeting to the speaker of the evening and announced the session adjourned.

WM. H. WAHL,
Secretary pro tem.

Stated meeting, held Thursday, April 27, 8 P.M. President Charles Day in the chair.

Present, 126 members and visitors.

The meeting was devoted to the discussion of the subject of Internal Combustion Engines. The discussion was opened by Prof. H. W. Spangler, who was followed by other speakers in the order given: Mr. John E. Codman, Philadelphia Bureau of Water; Mr. L. B. Goebbels, Otto Gas

Engine Co.; Mr. John D. MacPherson, American Diesel Engine Co.; Mr. John R. Bivins, Westinghouse Engine Co. The President likewise contributed to the discussion.

On account of the lateness of the hour, the further consideration of the subject was deferred until the next stated meeting. Adjourned.

Wm. H. Wahl,
Secretary pro tem.

ELECTRICAL SECTION. *Stated Meeting*, held Thursday, February 9, 1905. Mr. Thomas Spencer in the chair.

The paper of the evening was read by Mr. Washington Devereux, Electrical Engineer to the Philadelphia Fire Underwriters' Association, on the subject of "The Inspection of Electric Conductors, with Especial Reference to Fire Protection."

The speaker illustrated his theme by the exhibition of numerous lantern slides, models, etc., which strikingly demonstrated the dangers of faulty practice.

An informal discussion followed, which was freely participated in by the members and visitors present.

The President thanked those who had contributed to the proceedings of a highly interesting meeting, and adjourned the session.

Richard L. Binder,
Secretary.

A stated meeting of the Electrical Section was held on Thursday, March 30, 8 P.M., President Thos. Spencer in the chair.

The minutes of the last meeting were read and approved.

The paper of the evening was then read by Mr. E. H. Rushmore, of the Stanley Electrical Mfg. Co., Pittsfield, Mass., on "The Design and Manufacture of Alternating Current Generators."

Mr. Rushmore showed the great care and great amount of detail which must be taken care of in the manufacture of up-to-date apparatus and the accuracy to which the engineering problems, in designing machinery of this type, have attained.

There were seventy members and visitors present. A vote of thanks was accorded to Mr. Rushmore. There being no further business the meeting adjourned.

Richard L. Binder,
Secretary.

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—The 31st stated meeting of this Section was held on Thursday, February 23d, at 8 o'clock. Dr. Henry Leffmann in the chair. Present, 32 members and visitors.

Dr. Leffmann gave an informal description of certain "New Forms of Stereoscope, Spectroscope and Microscope, and New Applications Thereof."

In the course of his remarks, Dr. Leffman called attention to several improved forms of projecting apparatus, called the "Epidoscope," and the "Epidiascope," made by Carl Zeiss, of Jena, and showed sectional views of these devices on the screen.

Mr. Urbane C. Wanner exhibited a number of interesting photographic prints, and commented on them.

Following this communication there was an exhibition of lantern slides by Mr. J. H. Fenton and Mr. D. W. Ridpath. Adjourned.

M. I. WILBERT, *Secretary.*

The thirty-second meeting of the Section was held on Thursday, April 6th, at 8 P.M., Dr. Henry Leffmann in the chair.

Present, 42 members and visitors.

After the transaction of the regular business program, Dr. Leffmann and Mr. Hugo Bilgram exhibited and commented on a number of microscopic subjects—rocks and crystal sections, insects, etc.—which were shown on the screen by means of the projecting microscope. This was followed by a description of the construction, and a demonstration of the method of operating the "Graflex" camera by a representative of the manufacturers.

The remainder of the session was devoted to the exhibition of a number of lantern photographs representing scenes and landmarks in Lancaster county, Penna. These slides were loaned for the purpose by Mr. Webb, and were shown and commented upon by Dr. Leffmann.

The chairman thereupon adjourned the meeting.

MARTIN I. WILBERT,
Secretary.

The 33d stated meeting, held Thursday, May 4, 8 P.M. Dr. Henry Leffmann in the chair.

Present, 27 members and visitors.

The first communication of the evening was made by Mr. Howard W. DuBois, Mining Engineer, Philadelphia, on "A Simple Camera for Photographic Surveying," and incidentally, on "The Use of Hydrogen Peroxide as a Photographic Agent."

In connection with these subjects, Mr. DuBois showed a number of lantern photographs, illustrating various methods and camera constructions used for photographic surveying. Also a number of pictures, showing the reversal of the photographic image by prolonged exposure.

The subject was discussed by Dr. H. E. Wetherill, Dr. E. Goldsmith, the chairman and the author.

Dr. W. J. Williams, Chemist to the Frankford Arsenal, exhibited and gave a demonstration with some photographic flash powders of his invention.

Dr. Leffman followed with some remarks on the work of Dr. August Köhler, of Jena, Germany, in the use of ultra-violet light in photographs, and referred to the practical results obtained with apparatus made for the purpose by Carl Zeiss Co., of Jena. Adjourned.

M. I. WILBERT,
Secretary.

CHEMICAL SECTION.—Stated Meeting, held Thursday, March 23d, 8 P.M. Dr. E. Goldsmith in the chair.

Present, 32 members and visitors.

The paper of the evening was read by Mr. Richard L. Humphrey, on "The Manufacture of Portland Cement," in the course of which the speaker gave a historical sketch of this important industry, with especial reference to its development in the United States.

The subject was freely discussed, and at the close of the session a vote of thanks was passed to the speaker of the evening.

The Secretary reported the result of the ballot on the question of uniting the Physical and Chemical Sections. It was thereupon decided that the Committee on Sectional Arrangements be requested to authorize the union of the two Sections under the name of Section of Physics and Chemistry. Adjourned.

WM. H. WAHL,
Secretary pro tem.

SECTION OF PHYSICS AND CHEMISTRY.—Stated meeting, held Thursday, May 11, 8 P.M. Dr. Edward Goldsmith in the chair.

Present, 32 members and visitors.

The chairman introduced Dr. G. H. Meeker, Medico-Chirurgical College, Philadelphia, who exhibited and described a number of new forms of apparatus and methods in clenical chemistry. These included, a so-called micro-burette, come improvements in centrifugal apparatus; apparatus for the estimation of urea; a novel end reaction of the hypobromide test for urea; a so-called albumoscope; an apparatus for determining the percentage of fat in milk; an improved method of determining the alkalinity of blood; an improved analytical balance to permit of the weighing of bulky objects, and several minor devices and methods.

Discussed by Drs. H. F. Keller, W. J. Williams and the author.

The subject of Dr. Meeker's invention was referred to the Committee on Science and the Arts.

Dr. Henry Emerson Wetherill, of Philadelphia, followed with an exhibition and description of a number of new Diagnostic Instruments of his invention, including a new colorimetric scale in testing for for hæmoglobin, humidity of the skin, &c., several improved centrifugal machines for clinical and other uses, on the principle of the whirligig; an improved stethoscope, and other minor devices.

The Section passed a vote of thanks to the speakers of the evening.

The Secretary reported that a Board of Managers had approved the report of the Committee on Sectional Arrangements, recommending the consolidation of the Physical and Chemical Sections, under the title of the Section of Physics and Chemistry.

Adjourned.

WM. H. WAHL,
Secretary pro tem.

Franklin Institute.

(Proceedings of the Stated Meeting held Wednesday, April 19, 1905.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, APRIL 19, 1905.

PRESIDENT JOHN BIRKINBINE in the chair.

Present, 48 members and visitors.

Additions to membership since last report, 6.

The President introduced Mr. George S. Webster, Chief Engineer of the Bureau of Surveys, Department of Public Works, Philadelphia, who presented a carefully prepared paper on "The Improvement of the Delaware River and Harbor and the Landing Facilities of the Port of Philadelphia."

The paper was profusely illustrated with the aid of lantern photographs, and was freely discussed. The chairman extended the thanks of the meeting to the speaker of the evening, and announced the session adjourned.

WM. H. WAHL,
Secretary.

Proceedings of the Stated Meeting held Wednesday, May 17th, 1905.

HALL OF THE INSTITUTE,
PHILADELPHIA, MAY 17th, 1905.

VICE-PRESIDENT WASHINGTON JONES in the chair.

Present, 64 members and visitors.

Additions to membership since last report 8.

Prof. F. L. Garrison presented the first communication of the evening, giving his "Observations on the Geology and Mineral Resources of San Domingo." The speaker illustrated his remarks with the aid of a number of lantern photographs of views taken by himself during a recent professional trip through the Island. The subject was discussed by Dr. Edward Goldsmith and the author.

Prof. Lewis M. Haupt followed with some "Comments on the American International Ship Canal," in which he considered the comparative merits of the Panama and Nicaragua routes, illustrating his remarks with a series of lantern views. Prof. Garrison and the speaker discussed the subject.

The chairman extended the thanks of the meeting to the speakers of the evening and adjourned the meeting.

WM. H. WAHL,
Secretary.

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